PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXIV.

SESSION 1909-1910.

LIVERPOOL:

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—

1910.

CONTENTS.

I.—Proceedings.

II.—Transactions.

PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—87 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
1891—92 T. J. MOORE, C.M.Z.S.
1892—93 ALFRED O. WALKER, J.P., F.L.S.
1893—94 JOHN NEWTON, M.R.C.S.
1894—95 Prof. F. GOTCH, M.A., F.R.S.
1895—96 Prof. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—99 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.

SESSION XXIV., 1909-1910.

President:

R. NEWSTEAD, M.Sc., A.L.S.

Vice-Presidents:

W. T. HAYDON, F.L.S.

Prof. B. MOORE, M.A., D.Sc.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

MAY ALLEN, B.A.

Hon. Secretary:

JOSEPH A. CLUBB, D.Sc.

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Prof. PATERSON, M.D.
JOSEPH PEARSON, D.Sc.
Prof. SHERRINGTON, F.R.S.
E. THOMPSON.
L. R. THORNELY (Miss

Representative of Students' Section:

E. M. BLACKWELL (Miss).

REPORT of the COUNCIL.

During the Session 1909-10 there have been seven ordinary meetings and one field meeting of the Society.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

By invitation of the Council, Prof. J. H. Falkner Nuttall, F.R.S., of Cambridge, lectured before the Society, at the December Meeting, on "Ticks, and their relation to disease."

The Library continues to make satisfactory progress, and additional important changes have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Ordinary members - - - - - -	46
Associate members - - - - - -	3
Student members, including Students' Section -	32
Total - -	81

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-fourth session was held at the University, on Friday, October 15th, 1909.

The President-elect (R. Newstead, M.Sc., A.L.S.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1908-1909 (see "Proceedings," Vol. XXIII., p. viii.) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1908-1909 (see "Proceedings," Vol. XXIII., p. xviii.) was submitted and approved.

3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, W. T. Haydon, F.L.S., and Prof. B. Moore, D.Sc.; Hon. Treasurer, W. J. Halls; Hon. Librarian, May Allen, B.A.; Hon. Secretary, Joseph A. Clubb, D.Sc.; Council, H. C. Beasley, J. Johnstone, B.Sc., Oulton Harrison, Prof. Herdman, D.Sc., F.R.S., W. S. Laverock, M.A., B.Sc., Douglas Laurie, M.A., J. H. O'Connell, L.R.C.P., Prof. Paterson, M.D., Joseph Pearson, D.Sc., Prof. Sherrington, F.R.S., E. Thompson, and (Miss) L. R. Thornely.

4. R. Newstead, M.Sc., A.L.S., delivered the Presidential Address on "Some notes on the Natural History of Jamaica" (see "Transactions," p. 1). On the motion of Dr. O'Connell, a vote of thanks was carried with acclamation.

The second meeting of the twenty-fourth session was held at the University, on Friday, November 12th, 1909. The President in the chair.

1. Dr. Clubb reported the capture of a young Grey Seal (*Halichærus grypus*), stranded at Hoylake, and that the specimen was still living in the tanks in the Liverpool Museum Aquarium. This is the third record of this species for this neighbourhood.

2. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 3).

The third meeting of the twenty-fourth session was held at the University, on Tuesday, December 14th, 1909. The President in the chair.

1. Prof. J. H. Falkner Nuttall, F.R.S., of Cambridge, gave a lecture on "Ticks, and their relation to disease." The lecture was of great interest, and was illustrated by a number of original lantern slides. A cordial vote of thanks was passed on the motion of Prof. Herdman.

The fourth meeting of the twenty-fourth session was held at the University, on Friday, January 14th, 1910.

1. On the motion of the President, seconded by Prof. Herdman, the cordial congratulations of the Society were accorded to the members of the Liverpool Geological Society on the attainment of their Jubilee.

2. Mr. J. Johnstone, B.Sc., submitted the Annual Report of the Investigations carried on during 1909 in connection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 63).

3. Dr. Bassett supplemented the above Report by a description of his work on "The Salinity of the Irish Sea area."

The fifth meeting of the twenty-fourth session was held at the University, on Friday, February 11th, 1910. The President in the chair.

1. Mr. Edwin Thompson gave an interesting account, illustrated by apparatus, of his work in Photo-micrography.

The sixth meeting of the twenty-fourth session was held at the University, on Friday, March 11th, 1910. The Vice-President (Mr. W. T. Haydon) in the chair.

1. The following exhibits, with demonstrations, were made:—

   (*a*) Living Boas and Pythons, by Dr. O'Connell.

   (*b*) Living Stick Insects (*Bacillus rossii*), by Dr. Clubb.

   (*c*) Specimens and apparatus from the Zoological Laboratories, by Prof. Herdman and Dr. Pearson.

2. Dr. H. E. Roaf submitted a paper on the "Physiology of Marine Invertebrates," dealing specially with the digestive ferments.

The seventh meeting of the twenty-fourth session was held at the University, on Friday, May 6th, 1910. The President in the chair.

1. Dr. J. Travis Jenkins, Superintendent of Fisheries to the Lancashire County Council, gave a lecture on "Fishery Enquiries in Bengal," illustrated by a series of lantern slides prepared from the lecturer's negatives.

The eighth meeting of the twenty-fourth session was the Annual Field Meeting held at Delamere Forest, on Saturday, June 11th. Mr. Robert Newstead kindly acted as leader. At the short business meeting held after tea, on the motion of Prof. Herdman, Mr. R. Newstead, M.Sc., A.L.S., was unanimously re-elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1909-1910.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1908 Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.

1909 *Allen, Miss May, B.A., Hon. Librarian, Natural History Department, University.

1888 Beasley, Henry C., Prince Alfred Road, Wavertree.

1908 Bigland, H. D., B.A., Shrewsbury Road, Birkenhead.

1903 Booth, jun., Chas., 30, James Street, Liverpool.

1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.

1886 Clubb, J. A., D.Sc., Hon. Secretary, Free Public Museums, Liverpool.

1902 Glynn, Dr. Ernest, 67, Rodney Street.

1903 Guthrie, Dr. Thomas, 9, Canning Street, Liverpool.

1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.

1896 Haydon, W. T., F.L.S., Vice-President, 55, Grey Road, Walton, Liverpool.

1886 Herdman, Prof. W. A., D.Sc., F.R.S., University, Liverpool.

1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.

1897 Holt, Alfred, Crofton, Aigburth.

1902 Holt, A., jun., Crofton, Aigburth.

1903 Holt, George, 5, Fulwood Park, Liverpool.
1903 Holt, Richard D., M.P., 1, India Buildings, Liverpool.
1898 Johnstone, James, B.Sc., University, Liverpool.
1908 Jones, John Share, F.R.C.V.S., Vet. Department, University, Liverpool.
1894 Lea, Rev. T. S., M.A., The Vicarage, St. Austell, Cornwall.
1896 Laverock, W. S., M.A., B.Sc., Free Museums, Liverpool.
1906 Laurie, R. Douglas, M.A., University, Liverpool.
1905 Moore, Prof. B., Vice-President, University, Liverpool.
1908 Myres, Prof. J. L., University, Liverpool.
1904 Newstead, R., M.Sc., A.L.S., President, School of Tropical Medicine, Liverpool.
1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.
1904 Pallis, Miss M., Tätoi, Aigburth Drive, Liverpool
1894 Paterson, Prof., M.D., M.R.C.S., University, Liverpool.
1894 Paul, Prof. F. T., 38, Rodney Street, Liverpool.
1905 Pearson, J., D.Sc., Zoological Department, Liverpool.
1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.
1903 Rathbone, H. R., Oakwood, Aigburth.
1890 *Rathbone, Miss May, Backwood, Neston.
1909 Roaf, Dr. H. E., Physiological Department. University, Liverpool.
1897 Robinson, H. C., Malay States.
1908 Rock, W. H., 25, Lord Street, Liverpool.
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1895 Sherrington, Prof., M.D., F.R.S., University, Liverpool.

1886 Smith, Andrew T., 5, Hargreaves Road, Sefton Park.

1903 Stapledon, W. C., 2, Marine Park, West Kirby.

1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.

1905 Thompson, Edwin, 1, Croxteth Grove, Liverpool.

1889 Thornely, Miss L. R., Nunclose, Grassendale.

1888 Toll, J. M., 49, Newsham Drive, Liverpool.

1891 Wiglesworth, J., M.D., F.R.C.P., County Asylum, Rainhill.

1909 Whitley, Edward, Clovelly, Sefton Park, Liverpool.

B Associate Members.

1903 Tattersall, W., B.Sc., The Museums, Manchester.

1905 Harrison, Oulton, Denehurst, Victoria Park, Wavertree.

1905 Carstairs, Miss, 39, Lilley Road, Fairfield.

C University Students' Section.

President: E. M. Blackwell (Miss).

Hon. Secretary: G. A. Jackson (Miss).

Members:

The Misses G. Jackson, M. Jolley, M. Scott, D. Lawson, F. Uttley, A. Wildman, E. Horsman, L. Gleave, R. Robbins, R. Bamber, M. Firth, V. Gill, Blackledge, M. Heap, A. B. Dixon, E. Bland, A. Lennon, A. Lee, H. Coburn, M. Latarche, E. M. Blackwell, C. Beardsworth, Stubbs, Edge, G. Robinson, Hollinshead, Knight, Messrs. Waterhouse, Weston, Jackson, Nelson, Danier,

D HONORARY MEMBERS.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du brocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. **Cr.**

1909, Oct. 1st, to Sept. 30th, 1910.	£	s.	d.	1909, Oct. 1st, to Sept. 30th, 1910.	£	s.	d.
To Teas and Attendance at Meetings	3	0	6	By Balance from last Account	2	18	3
,, Attendance and Working Lantern	0	12	6	,, 18 Subscriptions	18	18	0
,, Postage and Carriage of Volumes	4	5	6	,, 2 Associate Members	1	1	0
,, Hon. Secretary's Expenses (postages, &c.)	2	4	0	,, 1 Entrance Fee	0	10	6
,, Hon. Librarian (postages, &c.)	1	0	0	,, 7 Subscriptions in Arrear	7	7	0
,, Cash in hand	0	10	0	,, 3 Subscriptions in Advance	3	3	0
,, Balance in Bank	30	17	0	,, Students' Section	0	15	0
				,, Sale of Volumes	7	10	7
				,, Bank Interest	0	6	2
	£42	9	6		£42	9	6

Audited and found correct,

HENRY C. BEASLEY.

LIVERPOOL, *October 7th, 1910.*

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

INAUGURAL ADDRESS

ON

THE NATURAL HISTORY OF JAMAICA.

By ROBERT NEWSTEAD, M.Sc., A.L.S., etc.,
President.

[Abstract.]

In his opening remarks the President expressed his warmest thanks to the Members of the Liverpool Biological Society for the distinguished honour which they had conferred upon him in electing him to the Presidential chair for the ensuing year. In recalling the names of the eminent men who had filled the office in previous years, he felt somewhat diffident in accepting the position which the members had bestowed upon him with such flattering cordiality.

The subject matter of the President's address was based upon experiences gained during a stay in the Island of Jamaica in the winter of 1908-9, while on a special expedition sent out by the Liverpool School of Tropical Medicine to study certain problems connected with tick-borne diseases in cattle, and also other pests connected with agriculture, etc.

After briefly discussing the physical features of the country and its chief geological characters, some of the more striking plant-forms were described, among which the curious Epiphytes (Bromeliaceae, etc.), the parasitic plants (*Cuscuta*, etc.), and some of the beautiful legumes may be mentioned. Some observations relating to the insect fauna of Jamaica were of interest from a bionomical point of view.

In dealing with the natural enemies of cattle-ticks (Ixodoidea), special reference was made to the dietary of the Horn-billed Cuckoo (*Crotophaga ani*), a bird which appeared to exercise little or no choice in the selection of its food, nauseous plant-bugs being eaten apparently just as freely as those insects which belong to the so-called edible group. In a series of post-mortem examinations many ticks were found in the contents of the stomachs; also many examples of the green "stink-bug" (*Loxa flavicollis*). This bug, whose odour is horribly offensive, does not possess any warning coloration; but being of a uniformly green colour is highly protected and difficult to discover when resting among the leafy branches of a tree or shrub. The amount of odoriferous matter contained in the stomachs of the birds found to contain the remains of this bug were so offensive as to render the operation of dissection positively unbearable, and the fœtid odour was with difficulty removed from the hands of the operator. The common "cotton stainer" (*Dysdercus* sp.), an hemipteron with a markedly warning orange-red colour pattern; nests of the paper-building wasp (*Polistes crinita*); huge black "witch moths" (*Erebus argarista*), measuring nearly six inches in the wing expanse; Geodephagous and Chrysomelid beetles; molluscs and berries; all of these were found to have been eaten by this bird.

In referring to the work of the Expedition, the President said that he was happy to be able to state that the practical experiments which he had conducted indicated that a most effective means of controlling cattle-ticks had been devised, and that highly satisfactory reports had been received from the Government in confirmation of this statement.

THE MARINE BIOLOGICAL STATION AT PORT ERIN,

BEING THE

TWENTY-THIRD ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

We have again to record a serious loss in the death of Mr. Lomas, an active and much valued member of the Committee, who was killed in a railway accident in the Algerian desert on the way to Biskra, on December 17th 1908.

Joseph Lomas, F.G.S., came to Liverpool from the Royal College of Science and School of Mines, South Kensington, where he had been a pupil of Huxley, Judd, Howes, Scott, and other famous teachers. He joined University College as a research student in 1885, and his first research in our laboratories was zoological—although it had a geological bearing too—being on the marine polyzoa, and especially those that build up limestone colonies often found fossil in the rocks. In fact, I think it is the case that throughout his original work the borderland between the two sciences, or rather the applications of zoological knowledge to the interpretation of geological appearances, had a special attraction for Lomas; and that, no doubt, accounted for his enthusiastic support of the Biological Society and the Liverpool Marine Biology Committee, and his helpful participation in our submarine explorations. His special function on these expeditions was to collect, examine, and report upon the nature and origin of the various deposits now being formed on the sea bottom, and to compare them with the more ancient ones that have

consolidated into the stratified rocks of the globe. Several of his published papers deal with such collections, and a series of the floor deposits of the Irish Sea, formed and classified under his guidance, is to be found not only in our own University Museum of Zoology, but also in the Museum of the Geological Survey at Jermyn Street, London.

Although in the main a geologist, Lomas often took part in our Biological expeditions, and frequently visited the Port Erin Station. He wrote a detailed report on the Polyzoa for the first volume of our "Fauna," and occasionally named series of specimens or wrote short notes for these Annual Reports. He was added to the Committee last November, just before he started on his fatal expedition to the Sahara. Most of his papers have, however, been Geological, and have appropriately dealt with the Triassic rocks of Lancashire and Cheshire, and Lomas had for several years recently been the secretary of a "Trias Committee" of the British Association, which has produced annual reports upon the extraordinary reptilian footprints and other remains found in profusion in certain beds exposed periodically by the quarrying operations at Storeton and elsewhere in the district. Lomas kept a watchful eye upon the progress of all such excavations, and it is due to his care and knowledge, and to his happy knack of interesting others in what he was studying, that many of the finest slabs of Cheirotheroid footprints have been saved from the quarrymen and are now preserved in our museums. Others of his papers and reports have dealt with glacial phenomena and with more recent changes in the configuration of the country (such as "The Coasts of Lancashire and Cheshire: their forms and origin"), while some have been of wider scope, such as his addresses

on the primeval rocks of the earth's crust, and upon "Comparative Lithology." But it is impossible now even to enumerate his various contributions to knowledge. All have been good, and though it cannot be claimed that Lomas has made any very great discovery, he has done much useful original work, carefully detailed and honestly set down. His reputation as a scientific man has been steadily growing amongst scientific men outside Liverpool, and for several years he has acted with marked success as the chief secretary of Section C (Geology) of the British Association.

Lomas was fortunate in obtaining grants from scientific funds, on occasions, to aid in his special investigations, and it was on such a journey—to inquire into the desert conditions in the neighbourhood of Biskra, with a view to a comparison with the Triassic rocks upon which Liverpool is built, and towards the expenses of which he had applied for and received a grant from the British Association at Dublin—that his useful life was prematurely cut short last December. As in the case of many another scientific man, his death came directly in the course of his scientific investigations.

For many years Lomas gave special courses of lectures on Geology and Physical Geography in the University. This volunteer teaching work, although sometimes it must have been heavy enough, was a labour of love, and was hardly, I fear, remunerative. His chief reward must have been the consciousness of the good work he was doing, and the gratitude of his students—several of whom have themselves become geologists.

Most of those who have worked with him will, however, agree that Lomas was at his best in "the field" on geological or biological expeditions. He was pre-eminently an open-air student of nature, and he could

lead a party over the country all day, and day after day, impressing upon them in the happiest manner both the minutiæ of rocks and fossils and the broad features of stratification and mountain building, or water drainage and the connection between landscape and geological structure. Many of us have recollections that will never fade of such days in Wales, or the Isle of Man, in the Lake Country, on the Yorkshire moors, and even in far South Africa. And beyond the earth-lore and all else that he taught us then and at other times, we shall ever remember the constant good nature and cheerful determination to make the best of everything, the helpful resourcefulness in times of difficulty, and the honest reliability and general sterling, lovable character of the friend we have lost.

I would again point out that, in view of the loss of so many of their old fellow-workers and supporters in the last year or two, the Committee are most anxious to get some younger men as recruits to fill the places thus left vacant, both as actual workers in the field and also as subscribers to the funds. There are now plenty of students—in fact, during the Easter vacation the Biological Station has, for the last few years, been practically full—and there are plenty of young professional researchers; but we have very few left of the earnest amateur naturalists who were our main support in the early days twenty years ago. The place left vacant on the Committee by the death of Mr. Lomas has been filled by the election of Dr. Benjamin Moore, Professor of Bio-Chemistry in the University of Liverpool. Professor Moore has for several years taken a keen interest

in the work of the Committee. He has on several occasions carried on research in vacations at the Port Erin Station, and in association with Mr. E. Whitley and Dr. H. E. Roaf has developed a new side to our work, viz., Bio-Chemistry and Comparative Physiology—a side of biological investigation which is most appropriate to a marine laboratory, and one which will probably be actively pursued in the future.

Fig. 1.—S.Y. "Ladybird," on a Plankton cruise at Easter, 1908, from a photo by Edwin Thompson.

The dredging, tow-netting and other investigations at sea, started two years ago with the yacht "Ladybird," have been carried on vigorously during the Easter and Summer vacations of 1909. Nearly 800 samples of plankton have been collected with various nets in the seas around Port Erin and have been sent to Mr. Andrew

Scott for microscopic investigation. During the Easter vacation Mr. W. Riddell, M.A., of Belfast, again gave me most valuable assistance in taking daily Plankton observations from the yacht. Mr. W. J. Dakin at the same time took charge of the corresponding Hydrographic work, and Mr. W. Gunn, from the Liverpool Laboratory, also gave efficient help. Some account of the results of these observations, and of the objects and methods of plankton-work in general, will be found further on in this Report.

FIG. 2.—The Biological Station and Fish Hatchery at Port Erin, from a photo by Edwin Thompson.

Our Hon. Treasurer, Mr. E. Thompson, at Easter, and Dr. F. Ward in Summer, were engaged in Photomicrographic study of developing fish embryos and other subjects. I am indebted to both these friends for beautiful photographs, from which some of the illustrations in this Report have been prepared.

The fish and lobster hatching, carried on for the Isle of Man Fisheries Board, will be found reported

on in detail below. Judged by the number of summer visitors, this has been a poor year in the Isle of Man generally, and as a natural consequence our numbers in the Aquarium record have fallen. We consider that under the circumstances we have not done badly in having between thirteen and fourteen thousand visitors who paid for admission. The institution, it will be remembered, is carried on jointly with the Fisheries Board, the receipts and the expenses being shared equally with that Authority.

As on previous occasions, Mr. Chadwick has supplied a "Curator's Report," which will be found below, and he has also, as usual, supplied me with details for some other parts of this Report.

THE STATION RECORD.

Forty naturalists and students have occupied the work-tables in the Laboratories for varying periods during the year, as follows:—

Dec. 28th to Jan. 9th.	Professor Herdman.—Official.
Feb. 20th to 22nd.	Professor Herdman.—Official.
March 26th to April 27th.	Professor Herdman.—Plankton.
,, ,,	Mr. W. Riddell.—Plankton.
April 1st to July 27th.	Mr. W. J. Dakin.—Sense organs of Mollusca.
April 3rd to 20th.	Dr. H. E. Roaf.—Physiology.
April 8th to 12th.	Mr. E. Thompson.—Photomicrography.
April 10th to 26th.	Mr. W. Gunn.—General.
April 13th to 27th.	Mr. R. D. Laurie.—Educational.
,,	Mr. Billington.—General.
April 13th to 22nd.	Mr. Johnson.—General.
April 14th to 27th.	Dr. Pearson.—Educational.
April 13th to 27th.	Mr. H. G. Jackson.
Miss E. M. Blackwell.	Miss M. Latarche.
Miss A. B. Dixon.	Miss A. Lee.
Miss K. Winston.	Miss A. G. Wildman.
Miss M. M. Heap.	Miss F. Uttley.
Miss E. Matthewman.	Miss M. Southerst.
Miss E. Bland.	Miss E. Horsman.
Miss M. Scott.	Miss A. Lennon.
Miss Prescott.	Miss T. A. Smith.
Miss L. W. Whitehurst.	Miss D. Lawson.

April 20th to 23rd	Mr. R. Williams Ellis.—General.
May 19th to June 10th.	Dr. Ward.—Photography of living Fishes.
July 7th to Aug. 9th.	Mr. F. H. Gravely.—Polychaeta.
July 7th to Aug. 19th.	Mr. S. Garside.—Marine Algae.
July 11th to 23rd.	Mr. Pryce.—General.
July 24th to Aug. 14th.	Miss C. E. Wetherall.—Polychaeta and Tunicata.
July 27th to Sept. 10th.	Dr. H. E. Roaf.—Physiology of Invertebrates.
July 31st to August 14th.	Mr. W. A. Gunn.—General.
Aug. 1st to 12th.	Professor Herdman.—Plankton.
Sept. 4th to 14th.	Mr. T. J. Evans.—General.
Sept. 4th to Oct. 2nd.	Dr. H. Henry.—Haemoflagellates of Fishes.
Sept. 27th to 30th.	Miss Wilkinson.—Crustacea.
Sept. and Oct. (occasional visits)	Mr. C. Okell.—General.
Nov. 29th to Dec. 17th.	Miss B. Watterson.—General.

The "Tables" in the Laboratory were occupied as follows:—

Liverpool University Table :—

Prof. Herdman. Mr. Dakin.
Dr. Roaf. Mr. Gunn.
Dr. Pearson. Mr. Billington.
Mr. Laurie. Miss B. Watterson.

Liverpool Marine Biology Committee Table :—

Mr. E. Thompson. Mr. R. Williams Ellis.
Dr. Ward. Mr. Pryce.
Dr. Henry. Mr. Evans.
Mr. C. Okell. Mr. Riddell.

Manchester University Table :—

Mr. Gravely. Mr. Garside.
Mr. Johnson. Miss Wilkinson.

Birmingham University Table :—

Miss Wetherall.

The following students of Liverpool University occupied the Junior Laboratory for a fortnight during the Easter vacation, and worked together under the supervision of Professor Herdman, Dr. Pearson and Mr. Laurie:—

Miss Lawson.	Miss Bland.	Miss Lee.
Miss Whitehurst.	Miss Southerst.	Miss Dixon.
Miss Smith.	Miss Matthewman.	Miss Latarche.
Miss Prescott.	Miss Uttley.	Miss Blackwell.
Miss Lennon.	Miss Heap.	Mr. Jackson.
Miss Scott.	Miss Wildman.	
Miss Horsman.	Miss Winston.	

Curator's Report.

Mr. Chadwick reports as follows:—

"The scientific work of the past year has been marked by some increase in the number of workers in our laboratories, and of researches which involved longer periods of time and more extensive use of the facilities afforded by the Station and its equipment. The Easter vacation class-work was again completely successful, and showed the advantage of a number of students working together under competent guidance and within easy reach of abundance of living material. Amongst the twenty-nine students and researchers who occupied tables during the year there were representatives of the Universities of Cambridge, Liverpool, Manchester, Birmingham and Sheffield.

"During the winter much time was devoted to careful revision and remounting of museum specimens. The whole of the collection of Molluscan shells was thus dealt with, and some new specimens were added.

"The study of Marine Plankton has again figured largely in the year's work. Tow-nettings have been taken twice a week, over a prescribed course in the bay, with as much regularity as the weather would permit, and a larger share in the laborious work of estimation and qualitative analysis of the gatherings has been undertaken by the Curator.

"The number of visitors to the Aquarium, compared with the records of the previous two years, shows a considerable falling off. This was clearly due to the fact that the Isle of Man as a whole did not enjoy its usual measure of patronage during the visitors' season. The tanks were as well stocked as in previous years, and there

was no indication of waning interest on the part of the 13,500 visitors who paid for admission. The number of copies of the 'Guide to the Aquarium' sold also shows a considerable falling off. We have abundant evidence, however, that this 'Guide' has been regarded by many visitors as a welcome addition to the popular literature of Marine Biology.

"Owing to the continued growth of living organisms in the circulation pipes, to which reference was made in last year's Report, it was found necessary to take down and thoroughly clean the whole system. This was done during the months of November and December, 1908; and at some points, especially the bends, the bore of the pipe was found to be almost completely obstructed by colonies of barnacles, mussels, and other molluscs. Before re-erection the lengths of piping were provided with flanges at their ends, so that it is now possible to remove and clean any length without disturbing the neighbouring ones.

"The tanks have been maintained in excellent condition by the Assistant Curator, and the mortality amongst the fishes and invertebrates has been quite insignificant. The largest conger has now been an inhabitant of the aquarium for nearly $4\frac{1}{2}$ years, and has attained a length of exactly 6 feet.* Another specimen, about 4 feet long, is the 'oldest inhabitant,' having occupied the same tank for over five years.

"The hatching season of 1909 fully justified the anticipation expressed by the Curator in last year's Report. The number of plaice larvæ hatched and liberated, 7,124,500, was nearly double that of the previous year, and brings the total number for the six

* This fish died on Friday, December 3rd. Its length was exactly 6 feet; maximum girth, 2 feet; weight, $59\frac{1}{2}$ lbs.

years during which the hatchery has been in operation to twenty-five and a half millions.

FIG. 3.—Mr. T. Cregeen collecting fish eggs from the surface of the spawning pond, from a photo by Edwin Thompson.

"The numbers of eggs collected and of larvæ set free during the season were as follows:—

Eggs collected.	Date.	Larvæ set free.	Date.
90,500	... February 22—26	78,000	... March 22
253,500	... February 27—March 3	184,500	... ,, 27
218,000	... March 4 and 5	148,000	... ,, 29
179,000	... ,, 6 and 8	146,000	... ,, 30
196,000	... ,, 9 to 12	126,000	... ,, 31
957,000	... ,, 13 to 17	766,500	... April 5
737,000	... ,, 18 to 20	609,000	... ,, 8
732,000	... ,, 22 and 23	603,000	... ,, 10
545,000	... ,, 24 to 26	400,000	... ,, 13
391,500	... ,, 27	286,500	... ,, 14
189,000	... ,, 29	147,000	... ,, 15
990,000	... ,, 30—April 3	754,000	... ,, 19

Eggs collected.		Date.	Larvæ set free.		Date.
619,000	...	April 5 and 6	441,000	...	„ 21
331,000	...	„ 7	257,000	...	„ 22
1,063,000	...	„ 8 and 9	849,000	...	„ 24
683,000	...	„ 12 and 13	520,000	...	„ 26
194,000	...	„ 14	142,000	...	„ 27
957,000	...	„ 15—20	667,000	...	May 3
9,325,500			7,124,500		

"A few thousands of additional fertilised eggs were collected on April 28th and May 10th; but the resulting larvæ were retained in the hatchery for scientific observation and experiment.

"The Curator regrets to say that, in spite of continued efforts and experiments on new lines, the problem of artificial lobster rearing remains practically unsolved. The initial difficulty—that of obtaining berried female lobsters with nearly ripe eggs—was greatly felt during the past season, and the total number of larvæ hatched did not reach 1,500. A wooden tank measuring 6 × 6 × 4 feet, with openings screened with wire gauze in the sides and bottom, was fixed in the western spawning pond, and an attempt was made to rear in it a number of lobster larvæ. This, in spite of abundant food material and liberal aeration of the water, proved a failure, none of the larvæ surviving the third stage of development. Mr. W. J. Ashburner, who made the tank, has further provided an apparatus for keeping the water therein in constant motion, and with this further experiments are to be made next summer. There is evidence that berried lobsters will retain their eggs if kept in the pond and provided with suitable hiding places; and the Curator is now accumulating a stock in the hope of ensuring a large number of larvæ next year.

"In response to an invitation by the Isle of Man Fisheries Board, representatives of the various Insular education authorities met in the junior laboratory on April 6th to hear an address from Professor Herdman on "Education," especially in its relations to modern science and modern requirements. The Deemster Callow occupied the chair, the Clerk of the Rolls and other members of the Council of Education were present, and in the course of the lecture Professor Herdman showed how an institution such as the Biological Station might be utilised by the schools of the Island for purposes of training in observation and for giving facilities to teachers in connection with some aspects of higher education."

Mr. Dakin's Report.

"The following is a brief account of some of the research carried out during my stay at Port Erin, which lasted four months, from April 1st until the end of July. My time was spent chiefly on three subjects, two of which are more or less related, and work on these was commenced at the Zoological Station of Naples. During the month of April, whilst Professor Herdman was at Port Erin, I took charge of the hydrographical observations made from his yacht, simultaneously with the plankton catches. There is now a very complete set of hydrographic apparatus at Port Erin, and I was able to fit up a small chemical laboratory with the necessary apparatus for the analysis of sea-water, so far as chlorine and oxygen are concerned. A very complete series of observations was made, which will be published in connection with Professor Herdman's Plankton Studies. After the Easter vacation, quantitative tow-nettings were taken regularly twice a week at a locality out at sea, two to three miles

west of the Breakwater, and these were continued until the first week in July. They demonstrated, probably for the first time in the Irish Sea, the length of the period of the vernal diatom maximum, which this year extended to May 24th.

"My other work dealt with the minute histology of the eye of *Pecten*, and a study of the visceral ganglion and the innervation of the osphradium in the Lamellibranchiata. The former research is being published in the Quarterly Journal of Microscopical Science, and a preliminary communication on the latter will be given here. Representatives of twelve genera belonging to nine sub-orders have been examined, and the course of the osphradial nerves has been traced by the method of serial sections. In several recent text-books, statements have been made, based apparently on a short paper of Pelseneer's, that the osphradium is innervated by the cerebral ganglion. Thus in the volume on the Mollusca in Ray Lankester's 'Treatise on Zoology,' we have 'The osphradial ganglion receives nerve fibre *not* from the visceral ganglion, but from the cerebral ganglion by way of the visceral commissure.' A similar statement occurs in Lang's 'Comparative Anatomy.' I find that in all the species examined, the osphradial nerve fibres arise from the branchial nerve, which takes its origin in the visceral ganglion, except in the case of *Pecten maximus*, where, in addition to this, two distinct nerves can be traced directly from the ganglion. No nerve fibres leave the cerebrovisceral connectives for the direct innervation of the osphradium.

"During the examination of some of these lamellibranchs, the remarkable Nemertean *Malacobdella* was discovered in the pallial cavity of *Venus casina*, and also in *Mya truncata* from Piel. The usual host is *Cyprina islandica*, but I am not aware of any previous records of

the occurrence of this Nemertean worm in the Port Erin district, or of its occurrence in these two molluscs, though Mr. Johnstone tells me he has found it in *Mya truncata* at Piel. It is probably not restricted to these three species.

"An interesting ciliate Infusorian, *Licnophora auerbachii*, which is also, I believe, a new record for the district, turned up on the tentacles of *Pecten maximus*.

"I should like to thank Professor Herdman, and also Mr. Chadwick, for the space allotted to me in the laboratory, which exceeded, I am afraid, very considerably the normal bounds, and for all the trouble they have taken to facilitate my work in various ways."

Mr. Gravely's Report.

"The stormy weather this summer interfered considerably with work on pelagic larvæ. For it was found that healthy specimens disappeared from the plankton during a storm, and did not return until almost all the sand which was stirred up had settled down again—a process which always took several days to complete. The only larva which I have to record as new to the bay is '*Ophiopluteus compressus*,' of the 'Nordisches Plankton,' a single specimen of which was taken on July 22nd. As this presents a mode of development not hitherto recorded in Ophiuroids, a description of it may be of some interest. The hydrocœl is situated on the left of the alimentary canal, and extends forwards slightly beyond the mouth, which would be perfectly symmetrical if it were not slightly drawn out into a point on the left side. The part of the hydrocœl near the mouth, however, will not eventually surround it, for it already bears at least two pairs of developing tube-feet: and (from the presence and position of similar papillæ on other parts of the larva, and of certain small plates that appear to be developed in

connection with the hydrocœl) it is evident that this is already star-shaped; that it is situated entirely on the left side of the pluteus and orientated as in Echinoplutei at this stage; and that the larval mouth will not take part in the formation of the permanent mouth. Moreover, as in *Echinus* again, there appears to be a membrane closing in an amniotic cavity, into which the tube-feet project. The plates of the Ophiuroid to which the larva gives rise have developed to such an extent that the 'terminal' plates of the arms project from the body in the form of a star, but (like the hydrocœl) instead of lying in the horizontal plane of the pluteus, as is usually the case at such an advanced stage of development, they lie in a plane at right angles to this—the plane in which they always make their first appearance in Ophioplutei. The plates of the aboral surface have reached a corresponding stage in their development, and also lie roughly in the plane of their original formation. These 'terminal' and aboral plates do seem to have moved very slightly towards the position assumed by those of other Ophioplutei, but this movement, as shown by the position of the middle of the central (aboral) plate, only amounts to a rotation through about 12° instead of 90°. It is unlikely, in view of the condition of the hydrocœl, that any further *rotation* will occur; but that some migration of plates will take place is shown by the position of the 'terminal' plate corresponding to the forwardly directed arm of the hydrocœl. This plate, as noted above, is still in its original position (i.e., near the stomach of the pluteus), whereas this arm of the hydrocœl extends beyond the mouth. Thus the directness of development found in *Echinus*, where the plates and soft parts arise together in their final relative positions, has not been fully acquired by this Ophiuroid.

"From this account it will be seen that the mode of development of *Ophiopluteus compressus*, whilst retaining traces of that usually found in Ophiuroids, is as a whole much more like that of Echinoids.

"A few specimens of the epauletted *Ophiopluteus* noted in my last year's report were again obtained. They are probably identical with Mortensen's *Ophiopluteus henseni*, a species described from a single specimen from Bermuda in the report of the German plankton expedition. The absence of the skeleton in Mortensen's specimen, however, must make any identification a little uncertain.

"The following Polychaets, all from under stones and Laminarian roots at Poyllvash, are, I believe, new to the L.M.B.C. area:—*Sphaerodorum* sp., *Nematonereis* sp., *Staurocephalus* sp., *Scoloplos* (*Theodisca*) *mamillata* (Clap.)—also found in Port Erin Bay below the Biological Station, *Polydora caeca* (Œrst.), and *Dodecaceria* (?? *concharum*, Œrst.).

"As all these worms were obtained in two short visits, a full investigation of the locality would probably yield many more new forms.

"Amongst the Laminarian roots a small specimen of the locally rare *Phascolosoma vulgare* was found, and a smaller Gephyrean was fairly abundant. The specimens of the latter are maggot-like creatures, 5-8 mm. in length, with an introvert of about 4-6 mm. The lophophore is represented, as in the genus *Petalostoma*, only by a pair of lobes which, however, vary a great deal in distinctness, and often appear to be entirely absent. Moreover, the Poyllvash species differs from the type (*P. minutum*, Ref.) in having only two instead of four retractors.

"As no investigations of the worm parasites of the

district appear to have been made as yet, I should like to record here the great abundance of the curious Gregarine *Ancora* (*Anchorina*, Ming.) *sagittata* in the gut of the common *Capitella* of Port Erin sands, and of the (?) ciliate *Anoplophrya* in the gut of *Cirratulus*."

Dr. Roaf's Physiological Work.

Dr. H. E. Roaf continued his investigations of last year* on the digestive processes in marine invertebrates. The results so far are partly in the form of observations on the nature of the food and the manner of feeding of several species, but more especially of *Echinus esculentus*, and partly experiments directed to determine the presence of acid or alkali in the alimentary canal during digestion. This latter investigation was carried out by using food dyed with chemical indicators, so that on examination after various periods of digestion the degree of the reaction could be determined. These experiments also gave some information as to the reaction of the organs, other than digestive, as the indicators when absorbed were capable of colouring the tissues in general.

A large white anemone (*Actinoloba dianthus*) was fed with pieces of fibrin soaked in methylene blue, with the result that the tentacles, and to a less extent the mouth-disc, became stained in a most striking manner. The blue tint is remarkably persistent, and remained unaltered for seven months, while the anemone was under observation in the tanks. Mr. Chadwick states that the colour has recently become re-distributed, and is now confined to a series of bands running circularly around the body-wall, and especially at the upper end close to the bases of the tentacles.

* Since published in the Bio-Chemical Journal, Vol. iii., 1908, pp. 462-472.

Whilst collecting large white anemones for this and similar work, Dr. Roaf found a specimen (see fig. 4) which was nearly divided into two distinct anemones. The mouth-discs and circles of tentacles are absolutely separate, but the two bodies join about two-thirds of the way up from the base. This is probably a case of partial fission, such as is known to occur sometimes in this and other anemones. G. H. Parker has described it in the

FIG. 4.—Specimen of *Actinoloba dianthus* showing fission.

American *Metridium marginatum*, and Dr. J. A. Clubb found the same in a Metridium (Actinoloba) from the Mersey, which completed its longitudinal fission in the tanks under his observation. Dr. Roaf found that when one mouth was fed with neutral-red stained food, the neighbouring tentacles became pink and remained coloured for four weeks, while those around the other mouth remained white. When one disc was stimulated the tentacles of that part contracted, and those of the other only followed more slowly after a slight interval, probably as a result of a secondary stimulation caused by the contracted state

of the neighbouring body exercising a pull upon the tissues. It is therefore inferred that in this "Siamese-twin" arrangement there is no communication between the digestive cavities and no direct nervous connection.

Dr. Roaf made a number of interesting observations on the manner in which *Echinus*, the Sea-urchin, catches its food and passes it around the body by means of its pedicellariæ, spines and tube feet, and on the movements of the teeth when the desirable particle is approaching the mouth. All of these investigations will be published in fuller detail in a paper to appear shortly.

Dr. Francis Ward's Photomicrographs.

(See Plates II and III, pp. 34 and 35).

"At the invitation of Professor Herdman, I show (Plates II and III) a few photographs of the early life-history of the plaice taken in the Fish Hatchery at Port Erin in May, 1909, and will describe the methods I employed in making these records of the living specimens.

No. 1 shows the Plaice Larva almost hatched, × 25.

"I noticed that during hatching the tail is frequently used as a fixed point; and then by spasmodic contractions of the back muscles the head and shoulders are made to impinge on the edge of the originally small rent in the egg membrane, until the opening is torn large enough to permit the larva to escape.

No. 2 shows the Plaice Larva hatching tail first, × 25.

"In photographing various larvæ hatching, I have observed that certain fish, e.g., the Perch (*Perca fluviatilis*), which have a very small yolk sac, hatch tail first, then the body, and lastly the head, through a small hole; but with Plaice larvæ, as with Salmonoid Alevins, hatching is delayed at the stage shown until the head also breaks through.

No. 3. Plaice Larva hatched 3 minutes, 6·5 mm. in length, × 15.

"In No. 3 the light was moved slightly to one side, so that the illumination was partly by transmitted and partly by reflected light, and the light being no longer directed into the lens, a dark background was obtained. This method is very useful in photographing delicate structures.

"Nos. 4 to 9 (Pl. III) show the changes by which the bi-laterally symmetrical larva becomes an asymmetrical flat fish. All are enlarged about 7 times.

No. 4. Larva just hatched, length 6·5 mm.

No. 5. Larva hatched 7 days, length 7·5 mm.

No. 6. Larva of length 9·5 mm.

No. 7. Larva of length 10 mm.

"This specimen shows a greater relative growth dorso-ventrally than longitudinally, a sign of commencing metamorphosis which is supposed to occur about the 30th day after hatching.

No. 8. Larva of length 11·5 mm.

"This shows the rotation of the cranium through its longitudinal axis, and the consequent carrying over of the left eye.

No. 9. Larva of length 13 mm.

"This shows the metamorphosis progressing, and the next stage examined showed it completed.

"The first five photographs were from ova or larvæ in the hatching boxes; the last four specimens were obtained from the spawning ponds at the Biological Station. All the specimens were photographed while alive, except No. 9. In this case I waited until the heart stopped beating, in order to show that structure satisfactorily.

"As to the apparatus used:—A deal board, four feet long and six inches wide, carried on one side two rails,

four inches apart, running the whole length. At one end of the board was screwed a 5 × 4 Planex Reflex camera. I removed the panel carrying the lens, and temporarily fixed on a 10-inch wooden extension for the lower magnifications, and a longer extension made with wire and brown paper for the higher magnifications. These extensions ran along the rails as the camera was racked out. A 2-inch block of wood, also running on the rails,

FIG. 5.—Four stages in the early development of the Plaice before hatching. From photomicrographs by Edwin Thompson.

carried a cell in which was the living larva in sea-water. A second block of wood carried an 8-inch condenser. The illumination was obtained from an acetylene bicycle lamp.

"The lens used for photographs 1, 2 and 3 was a Zeiss micro-planar of 35 mm. focal length; and for photographs 4 to 9 a 3½-inch Beck. The lenses were stopped down

from F 11 to F 16, and the exposures varied from 10 to 15 seconds.

"For this kind of work the best lens is one of about 3-inch focal length, the magnification being obtained by having the plate a considerable length from the lens; by this means the whole thickness of the object to be photographed can be brought into focus without having to use a small stop and so sacrifice light.

"These photographs were taken with the cell in a vertical position, and the cell used was just the depth of the object to be photographed, which object was kept in position by the cover glass. This method entails considerable trouble, and there is a danger that the specimen may be compressed.

"Since returning from Port Erin I have constructed a more elaborate apparatus, so as to be able on my next visit to photograph specimens with the cell in a horizontal position, and so avoid all risk of compression.

"I have to thank Mr. Chadwick, and his assistant, Mr. T. Cregeen, for the immense trouble they took in procuring suitable specimens in the successive stages, and Mr. W. J. Dakin for many useful suggestions."

In addition to the above described work by Dr. F. Ward, our Hon. Treas., Mr. Edwin Thompson, has devoted much attention during the year to making Photomicrographs of living Plankton. Fig. 5 shows four of his series illustrating the embryonic development of the plaice. These all represent earlier stages than those figured by Dr. Ward (Pl. II.), which commenced with the hatching of the larvæ. Mr. Thompson has also prepared a number of photomicrographs of typical samples of different kinds of plankton, and a few of these are shown in Pl. I., p. 33.

"OUR FOOD FROM THE SEA."

It is plain, from questions that have been asked from time to time by readers of these Annual Reports and by visitors to the Biological Station, that some of our supporters, both in Liverpool and the Isle of Man, would be glad of further information as to the nature of "Plankton," and as to the method and object of that Plankton investigation to which so much attention has been devoted during recent years. I shall therefore quote here, with a few alterations and additions, some paragraphs from an address on "Our Food from the Waters," given before the British Association, at Winnipeg, this autumn—the argument being that the marketable fish which man obtains from the sea and from fresh-waters are ultimately dependent for existence upon the minute plants and animals found in varying quantity in all waters, and known as "Plankton"; and that in collecting, examining and attempting to estimate the quantities of such organisms, under different conditions, and to account for the marked variations in these quantities, the Biologist is dealing with important economic questions, and at the same time is brought face to face with some of the greatest world problems still unsolved by science.

It is possible to collect samples of the surface Plankton of the sea in any required quantity per day or hour from an ocean liner going at full speed, and such gatherings have now been made from traverses across several of the great oceans. The method is simple, effective, and inexpensive: and the gatherings, if taken continuously, give a series of samples amounting to a section through the surface layer of the sea, a certain volume of water being pumped in continuously through

the bottom of the ship, and strained through the fine silk nets, the mesh of which may be the three-hundredth of an inch across, before passing out into the sea again. In examining with a microscope such a series of gatherings across an ocean, two facts are brought prominently before the mind:

FIG. 6.—The Hensen Quantitative Net.

(1) The constant presence of a certain amount of minute living things;

(2) The very great variation in the quantity and in the nature of these organisms.

Such Plankton gatherings taken continuously from an ocean liner give, however, information only in regard to the *surface* fauna and flora of the sea—including many organisms of fundamental importance to man as the immediate or the ultimate food of fishes and whales and other useful animals.

It was therefore a great advance in Planktology when Professor Victor Hensen (1887) introduced his vertical, quantitative nets (fig. 6) which could be lowered down and drawn up through any required zones of the water. The highly original ideas and the ingenious methods of Hensen and his colleagues of the Kiel School of Planktology—whether all the conclusions which have been drawn from their results be accepted or not—have at the least inaugurated a new epoch in such oceanographic work; and have inspired a large number of disciples, critics and workers in most civilised countries, with the result that the distribution of minute organisms in the oceans and the fresh waters of the globe is now much more fully known than was the case twenty, or even ten, years ago. But perhaps the dominant feeling on the part of those engaged in this work is that, notwithstanding all this activity in research and the mass of published literature to which it has given rise, much still remains to be done, and that the Planktologist is still face to face with some of the most important unsolved problems of Biology.

The fundamental ideas of Hensen were that the Plankton, or assemblage of more or less minute drifting organisms (both animals and plants) in the sea, is uniformly distributed over an area where the physical conditions are approximately the same, and that by taking a comparatively small number of samples it would be possible to calculate the quantity of Plankton contained

at the time of observation in a given sea area, and to trace the changes of this Plankton both in space and time. This was a sufficiently grand conception, and it has been of great service to science by stimulating many workers to further research. In order to obtain answers to the problems before him, Hensen devised nets of the finest silk of about 6,000 meshes in the square centimetre, to be hauled up from the bottom to the surface, and having their constants determined so that it was known what volume of water passed through the net under certain conditions. (See figure of the silk on Pl. IV., p. 36).

Now, if this constancy of distribution postulated by Hensen could be relied upon over considerable areas of the sea, far-reaching conclusions, having important bearings upon fisheries questions, might be arrived at; and such have, in fact, been put forward by the Kiel Planktologists and their followers, and have been quoted on many occasions.

Such generalisations are most attractive, and if it can be established that they are based upon sufficiently reliable data, their practical utility to man in connection with sea-fishery legislation will be very great. But the comparatively small number of the samples, and the observed irregularity in the distribution of the Plankton, such as the examples given for the Irish Sea in the last two of these Annual Reports, and over still wider areas such as the North Sea, leave the impression that further observations are required before such conclusions can be accepted as established.

Of the criticisms that have appeared in Germany, in the United States and elsewhere, the two most fundamental are: (1) that the samples are inadequate; and (2) that there is no such constancy and regularity in distribution as Hensen and some others have supposed.

It has been shown by Kofoid, by Lohmann, and by others that there are imperfections in the methods which were not at first realised, and that under some circumstances anything from 50 to 98 per cent. of the more minute organisms of the Plankton may escape capture by the finest silk quantitative nets. The mesh of the silk is

FIG. 7.—Closing Petersen-Hensen Net going down open.

FIG. 8.—The same quantitative plankton net coming up closed.

1-300th inch across, but many of the organisms are only 1-3000th inch in diameter, and so can readily escape.

Other methods have been devised to supplement the Hensen nets, such as the filtering of water pumped up through hose-pipes let down to known depths, and also the microscopic examination in the laboratory of the centrifuged contents of comparatively small samples of

water obtained by means of closing water-bottles from various zones in the ocean. But even if deficiencies in the nets be thus made good by supplementary methods, and be allowed for in the calculations, there still remains the second and more fundamental source of error, namely, unequal distribution of the organisms in the water; and in regard to this a large amount of evidence has now been accumulated, since the time when Darwin, during the voyage of the "Beagle" on March 18, 1832, noticed off the coast of South America vast tracts of water discoloured by the minute floating Alga, *Trichodesmium erythræum*, which is said to have given its name to the Red Sea, and which Captain Cook's sailors in the previous century called "sea-sawdust." Many other naturalists since have seen the same phenomenon, caused both by this and by other organisms. It must be of common occurrence, and is widespread in the oceans, and it will be admitted that a quantitative net hauled vertically through such a Trichodesmium bank would give entirely different results from a haul taken, it might be, only a mile or two away, in water under, as far as can be determined, the same physical conditions, but free from Trichodesmium.

Nine nations bordering the North-West seas of Europe, some seven or eight years ago, engaged in a joint scheme of biological and hydrographical investigation, mainly in the North Sea, with the declared object of throwing light upon fundamental facts bearing on the economic problems of the fisheries. One important part of their programme was to test the quantity, distribution, and variation of the Plankton by means of periodic observations undertaken four times in the year (February, May, August and November) at certain fixed points in the sea. Many biologists considered that these periods were too few and the chosen stations too far apart to give

reliable results. It is possible that even the original promoters of the scheme would now share that view, and the opinion has recently been published by the American Planktologist, Professor C. A. Kofoid—than whom no one is better entitled, from his own detailed and exact work, to express an authoritative verdict—that certain recent observations "can but reveal the futility of the Plankton programme of the International Commission for the investigation of the sea. The quarterly examinations of this programme will, doubtless, yield some facts of value, but they are truly inadequate to give any reliable view of the amount and course of Plankton production in the sea."*

It is evident that before we can base far-reaching generalisations upon our Plankton samples, a minute study of the distribution of life in both marine and fresh waters at very frequent intervals throughout the year should be undertaken. Kofoid has made such a minute study of the lakes and streams of Illinois, and C. D. Marsh of those of Wisconsin; and similar intensive work is now being carried out at several localities in Europe.

Too little attention has been paid in the past to the distribution of many animals in swarms, some parts of the sea being crowded and neighbouring parts being destitute of such forms, and this not merely round coasts and in the narrow seas, but also in the open ocean. For example, some species of Copepoda and other small crustacea occur notably in dense crowds (fig. 11, Pl. I), and are not universally distributed. This is true also of some of the Diatoms, and also of larger organisms. Many naturalists have remarked upon the banks of Trichodesmium, of Medusæ and Siphonophora, of Salpæ, of Pteropods, of Peridinians and of other

* "Internationale Revue der Hydrobiologie und Hydrographie," Vol. I., p. 846, December, 1908.

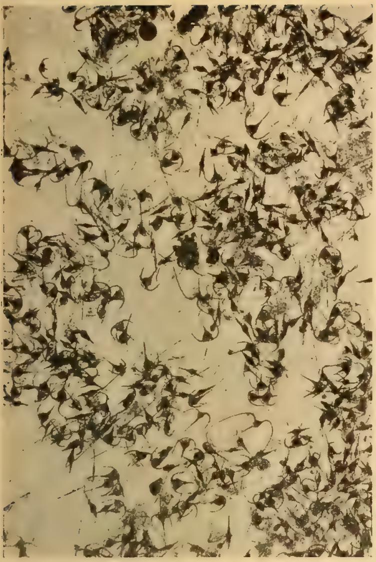


FIG. 9. Peridinian Plankton, consisting mainly of *Ceratium tripos*.

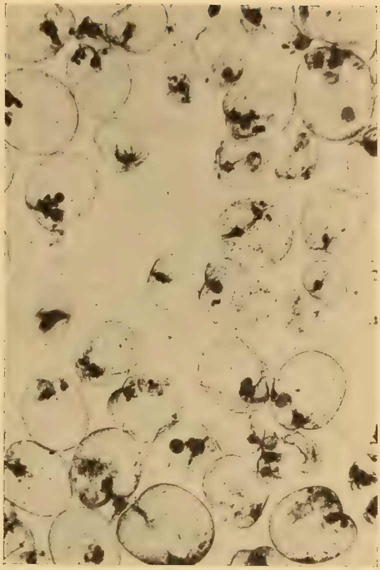
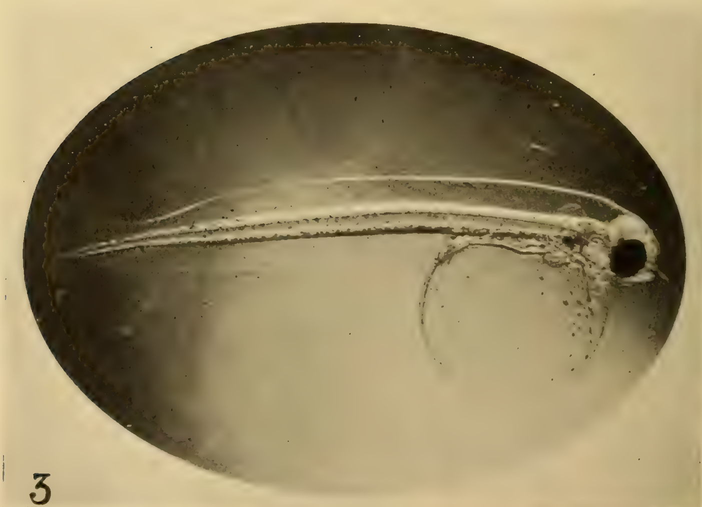


FIG. 10. Plankton, consisting almost wholly of *Noctiluca miliaris*.

FIG. 11. Copepod Plankton, consisting mainly of *Acartia discaudata*. One *Temora* is seen.

FIG. 12. Diatom Plankton, consisting mainly of *Coscinodiscus* and *Biddulphia*.



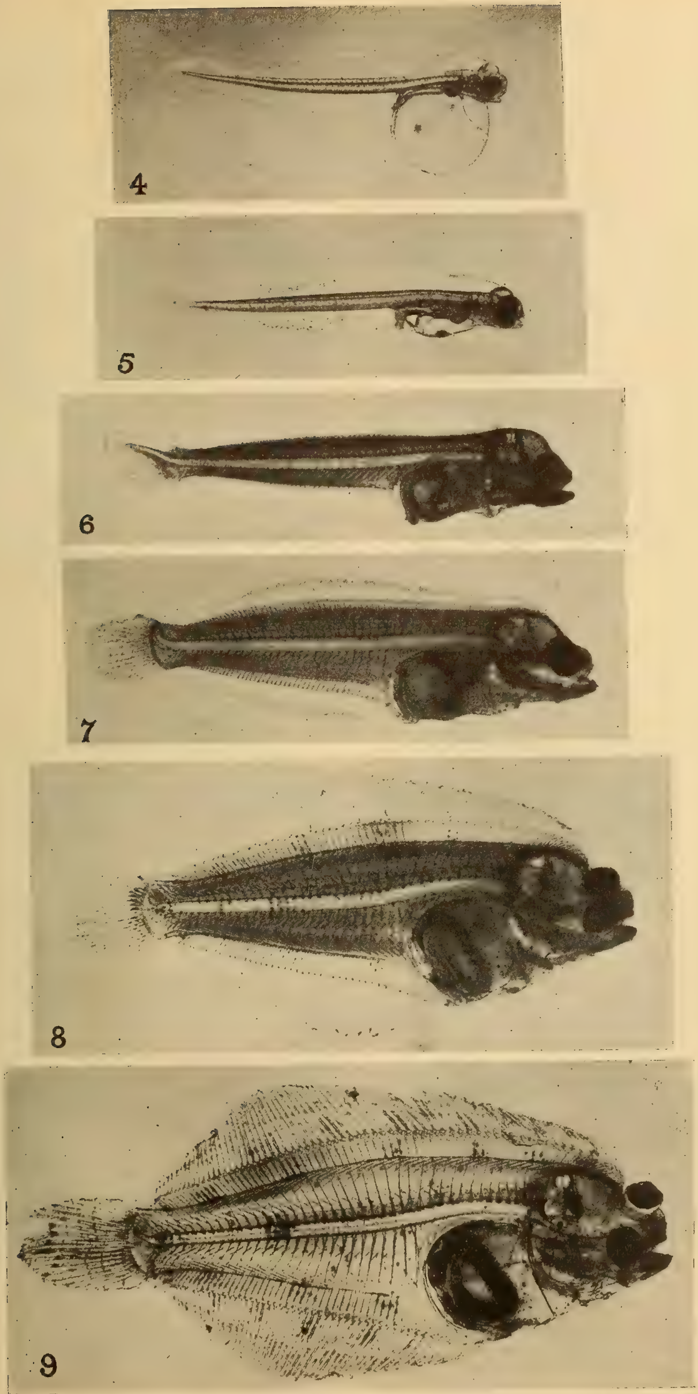

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FIG. 18. Nauplius stage of *Balanus*.

FIG. 19. Cypris stage of *Balanus*.

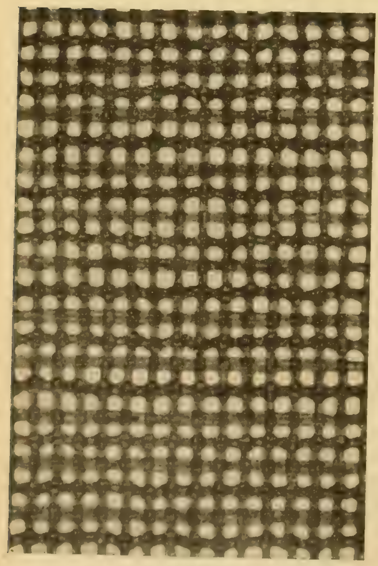


FIG. 20. Mesh of No. 20 silk when new. × 23

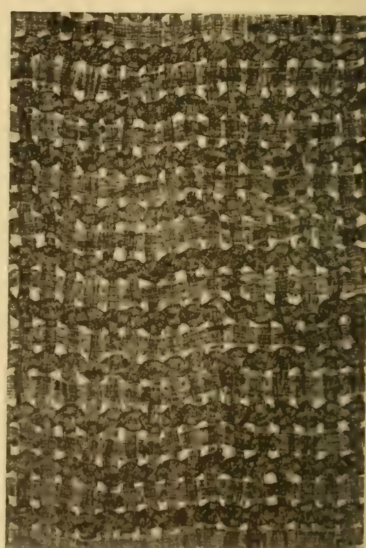


FIG. 21. Mesh of same silk after use in Nansen net for some months. × 23

common constituents of the Plankton. It is possible, however, that in some parts of the ocean, far from land, the Plankton may be distributed with the uniformity supposed by Hensen. It is important to recognise that at least three classes of locality exist in the sea in relation to distribution of Plankton:—

(1) There are estuaries and coastal waters where there are usually strong tidal and other local currents, with rapid changes of conditions, and where the Plankton is largely influenced by its proximity to land.

(2) There are considerable sea areas, such as the centre of the North Sea and the centre of the Irish Sea, where the Plankton is removed from coastal conditions, but is influenced by various factors which cause great irregularity in its distribution. These are the localities of the greatest economic importance to man, and to which attention should especially be directed.

(3) There are large oceanic areas in which there may be uniformity of conditions, but it ought to be recognised that such regions are not those in which the Plankton is of most importance to men. The great fisheries of the world, such as those of the North Sea, the cod fishery in Norway, and those on the Newfoundland Banks, are not in mid-ocean, but are in areas around the continents, where the Plankton is irregular in its distribution.

As an example of a locality of the second type, showing seasonal, horizontal and vertical differences in the distribution of the Plankton, we may take the centre of the Irish Sea, off the south end of the Isle of Man. Here, as in other localities which have been investigated, the Phyto-Plankton is found to increase greatly about the time of the vernal equinox, so as to cause a maximum, largely composed of Diatoms, at a period ranging from the end of March to some time in May. During this period

the eggs of most of the edible fishes are hatched as larvæ. Figure 13 shows the curve formed by the catches of the total plankton in Port Erin Bay during 1908.

This Diatom maximum is followed by an increase in the Copepoda (minute crustacea), which lasts for a considerable time during the early summer; and as the fish larvæ and the Copepoda increase there is a rapid falling off in Diatoms. Less marked maxima of both Diatoms and Copepoda may occur again about the time of the autumnal

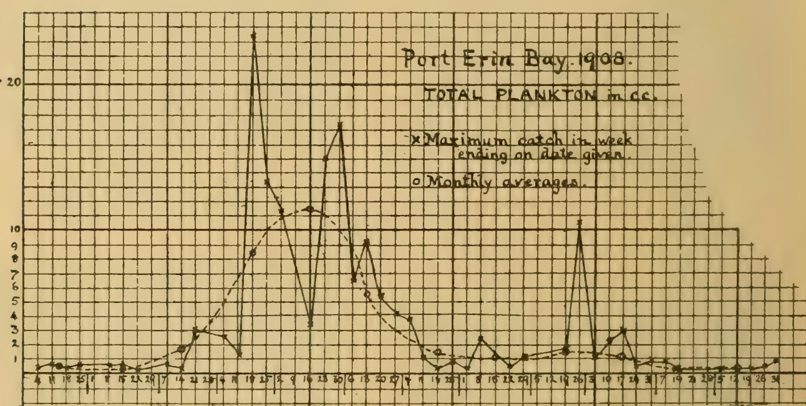


FIG. 13.

equinox. These two groups—the Diatoms (fig. 12) and the Copepoda (fig. 11)—are the most important economic constituents in the Plankton. A few examples showing their importance to man may be given:—Man eats the oyster and the American clam, and these shell-fish feed upon Diatoms. Man feeds upon the cod, which in its turn may feed on the whiting, and that on the sprat, and the sprat on Copepoda, while the Copepoda feed upon Peridinians and Diatoms; or the cod may feed upon crabs, which in turn eat "worms," and these feed upon smaller forms which are nourished by the Diatoms. Or, again, man eats the

mackerel, which may feed upon young herring, and these upon Copepoda, and the Copepoda again upon Diatoms. All such chains of food matters from the sea seem to bring one through the Copepoda to the Diatoms, which may be regarded as the ultimate "producers" of food in the ocean. Thus the living food of man from the waters of the globe may be said to be the Diatoms and other microscopic organisms quite as much as the fishes.

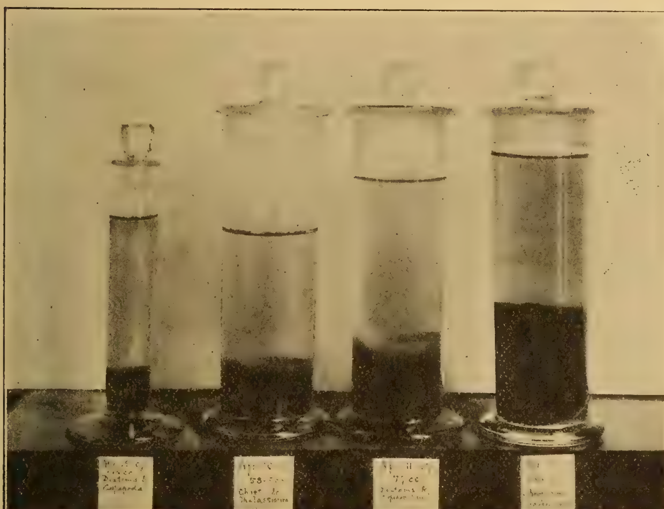


FIG. 14.—Four samples of plankton taken with the same net, in the same locality, between April 5th and 15th, 1907, and ranging from 13 c.c. to 100 c.c.

Two years ago, at the Leicester meeting of the British Association, I showed that if an intensive study of a small area be made, hauls being taken not once a quarter or once a month, but at the rate of ten or twelve a day, abundant evidence will be obtained as to: (1) variations in the distribution of the organisms, and (2) irregularities in the action of the nets. Great care is necessary in order to

ensure that hauls intended for comparison are really comparable. Two years' additional work since in the same locality, off the south end of the Isle of Man, has only confirmed these results, viz., that the Plankton is liable to be very unequally distributed over the depths, the localities, and the dates. One net may encounter a swarm of organisms which a neighbouring net escapes, and a sample taken on one day may be very different in quantity from a sample taken under the same conditions next day. If an observer were to take quarterly, or even monthly, samples of the Plankton, he might obtain very different results according to the date of his visit. For example, on three successive weeks about the end of September he might find evidence for as many different far-reaching views as to the composition of the Plankton in that part of the Irish Sea. Consequently, hauls taken many miles apart and repeated only at intervals of months can scarcely give any sure foundation for calculations as to the population of wide sea areas.

These conclusions need not lead us to be discouraged as to the ultimate success of scientific methods in solving what may be called world-wide problems, but they suggest that it would be wise to secure by detailed local work a firm foundation upon which to build, and to ascertain more accurately the representative value of our samples before we base conclusions upon them.

I do not doubt that in limited, circumscribed areas of water, in the case of organisms that reproduce with great rapidity, the Plankton becomes more uniformly distributed, and a comparatively small number of samples may then be fairly representative of the whole. That is probably more or less the case with fresh-water lakes; and I have noticed it in Port Erin Bay in the case of Diatoms. In spring, and again in autumn, when suitable

weather occurs, as it did two years ago at the end of September, the Diatoms may increase enormously, and in such circumstances they seem to be very evenly spread over all parts and to pervade the water to some depth; but that is emphatically not the case with the Copepoda and other constituents of the Plankton, and it was not the case even with the Diatoms during the succeeding year.

I have published in a former report an observation

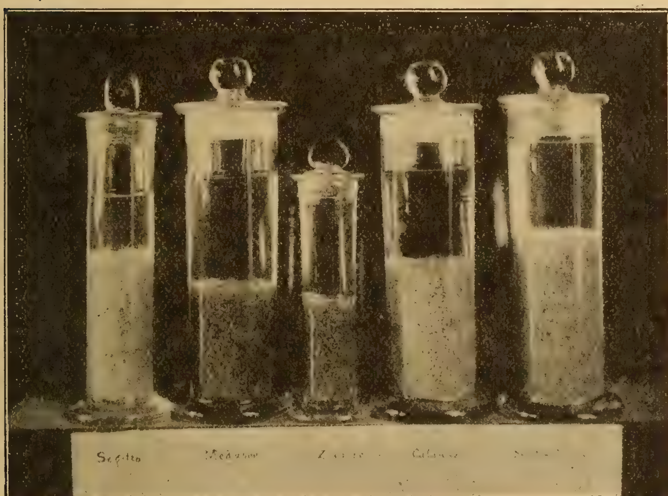


Fig. 15.—Series of plankton gatherings showing "swarms" of certain organisms (Haeckel's "Monotones Plankton").
The jars contain mainly Sagitta, Medusæ, Zoëa, Calanus, and smaller Copepoda, going from left to right.

that showed very definite limitation of a large shoal of crab Zoëas, so that none were present in one net while in another adjacent haul they multiplied several times the bulk of the catch and introduced a new animal in enormous numbers. Had two expeditions taken samples that evening at what might well be considered as the same station, but a few hundred yards apart, they would have

arrived at very different conclusions as to the constitution of the Plankton in that part of the ocean.

It is possible to obtain a great deal of interesting information in regard to the "hylokinesis" (or changes of matter) of the sea without attempting a numerical accuracy which is not yet attainable. The details of measurement of catches and of computations of organisms become useless, and the exact figures are non-significant, if the hauls from which they are derived are not really comparable with one another and the samples obtained are not adequately representative of nature. If the stations are so far apart and the dates are so distant that the samples represent little more than themselves, if the observations are liable to be affected by any incidental factor which does not apply to the entire area, then the results may be so erroneous as to be useless, or worse than useless, since they may lead to deceptive conclusions. It is obvious that we must make an intensive study of small areas before we draw conclusions in regard to relatively large regions such as the North Sea or the Atlantic Ocean.

That, however, is not an argument against the legitimate use of quantitative methods, with limitations, and for certain purposes. It is necessary to know more than the fact that a certain species is present at a given locality at a certain time. We must endeavour to get some measure of its abundance, and that can only be done satisfactorily by counting individuals; at the same time recognising the imperfections of the methods and the approximate nature of the result, so that the numerical estimate will be regarded as relative rather than absolute. Our apparatus is not perfect enough, nor is the distribution of the organisms sufficiently uniform to enable us to calculate how many individuals of a Diatom, of a Copepod, or of a fish are present in the Irish Sea on a

particular occasion; but we may aim at being able to make, with a reasonable approximation to the truth, such statements as: There are about ten times as many Diatoms in a special part of the Irish Sea now as there were last week, and in round numbers twice as many as at the corresponding period of last year.

With the object of formulating such views as to the nature of the Plankton at any particular time, and as to

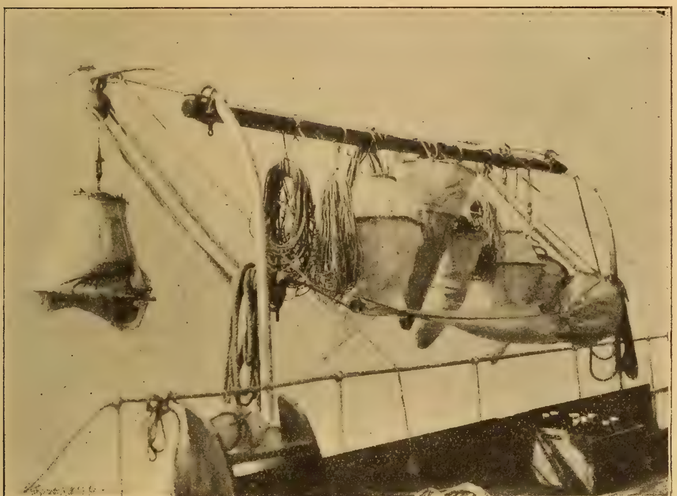


FIG. 16.—Plankton nets drying after an expedition on S.Y. "Ladybird" at Port Erin. (Photo by Edwin Thompson).

the changes, both diurnal and seasonal, and the determining factors of such changes, we must endeavour to make quantitative catches as accurately and as frequently as possible, so that our samples may be as nearly representative and as nearly comparable one with another as the difficult conditions will admit. These catches should be made with standard nets, should be preserved and measured according to a uniform system, and may then be compared in bulk; but, in addition, the more important

organisms should be counted approximately, and the results, in round numbers, may be used in comparing catches or in tracing changes; but such figures should not be made the basis of calculations as to the total numbers of such organisms in the oceans. In brief, the numerical results of quantitative work should be regarded as giving *relative* but not *absolute* information.

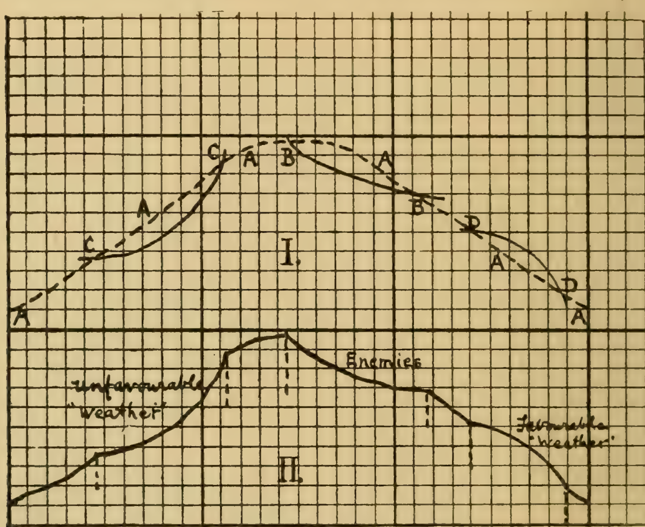


FIG. 17.—Diagram showing the influence of the factors C, B, D, upon the life-history A.

The factors causing the seasonal and other variations in the Plankton already pointed out may be grouped under three heads, as follows:—

(1) The sequence of the stages in the normal life history of the different organisms.

(2) Irregularities introduced by the interactions of the different organisms.

(3) More or less periodic abnormalities in either time or abundance caused by the physical changes in the sea, which may be grouped together as "weather."

These are all obvious factors in the problem, and the constitution of the Plankton from time to time throughout the year must be due to their interaction. The difficulty is to disengage them from one another so as to determine the action of each separately (See fig. 17 which illustrates the effect of the above factors).

Figure 18, on Plate IV, shows the Nauplius stage of the common rock barnacle (*Balanus*). The adult is present in abundance on the rocks at Port Erin, and the Nauplii are sometimes found in enormous swarms in spring. Figure 19 shows the succeeding or "Cypris" stage, found in our tow-nets a little later and in much smaller quantities than the Nauplius—the reduced numbers in the later stage of the life-history being evidence of the action of enemies and other factors of the environment.

Amongst the physical conditions coming under the third heading, the temperature of the sea is usually given a very prominent place. I shall allude here to one aspect only of this matter.

It is often said that tropical and sub-tropical seas are relatively poor in Plankton, while the colder Polar regions are rich. In fishing Plankton continuously across the Atlantic it is easy from the collections alone to tell when the ship passes from the warmer Gulf Stream area into the colder Labrador current. This is the reverse of what we find on land, where luxuriant vegetation and abundance of animal life are characteristic of the tropics in contrast to the bare and comparatively lifeless condition of the Arctic regions. Brandt has made the ingenious suggestion that the explanation of this phenomenon is that the higher temperature in tropical seas favours the action of denitrifying bacteria, which therefore flourish to such an extent in tropical waters as seriously to diminish the

supply of nitrogen food and so limit the production of Plankton. Loeb,* on the other hand, has recently revived the view of Murray, that the low temperature in Arctic waters so reduces the rate of all metabolic processes, and increases the length of life, that we have in the more abundant Plankton of the colder waters several generations living on side by side, whereas in the tropics with more rapid metabolism they would have died and disappeared. The temperature of the sea-water, however, appears to have little or no effect in determining the great vernal maximum of Phyto-Plankton.

Considering the facts of photosynthesis, there is much to be said in favour of the view that the development, and possibly also the larger movements, of the Plankton are influenced by the amount of sunlight, quite apart from any temperature effect.

Bullen† showed the correlation in 1903-07 between the mackerel catches in May and the amount of Copepod Plankton in the same sea. The food of these Copepoda has been shown by Dakin to be largely Phyto-Plankton; and Allen has lately‡ correlated the average mackerel catch per boat in May with the hours of sunshine in the previous quarter of the year, thus establishing the following connection between the food of man and the weather:—Mackerel—Copepoda—Diatoms—Sunshine. One more example of the influence of light may be given. Kofoid has shown that the Plankton of the Illinois River has certain twenty-nine-day pulses, which are apparently related to the lunar phases, the Plankton maxima lagging about six days behind the times of full moon. The light from the sun is said to be 618,000 times as bright as that

* *Darwin and Modern Science* (Cambridge, 1909), p. 247.

† M.B.A. Journ., viii. 269. ‡ M.B.A. Journ., vii. 394.

from the full moon; but the amount of solar energy derived from the moon is sufficient, we are told, appreciably to affect photosynthesis in the Phyto-Plankton. The effectiveness of the moon in this photosynthesis to that of the sun is said to be as two to nine, and, if that is so, Kofoid is probably justified in his contention that at the time of full moon the additional light available has a marked effect upon the development of the Phyto-Plankton.

As on land, so in the sea, all animals ultimately depend upon plants for their food. The plants are the producers and the animals the consumers in nature, and the pastures of the sea, as Sir John Murray pointed out long ago, are no less real and no less necessary than those of the land. Most of the fish which man uses as food spawn in the sea at such a time that the young fry are hatched when the spring Diatoms abound, and the Phyto-Plankton is followed in summer by the Zoo-Plankton (such as Copepoda), upon which the rather larger but still immature food fishes subsist. Consequently the cause of the great vernal maximum of Diatoms is one of the most practical of world problems, and many investigators have dealt with it in recent years. Murray first suggested that the meadows of the sea, like the meadows of the land, start to grow in spring simply as a result of the longer days and the notable increase in sunlight. Brandt has put forward the view that the quantity of Phyto-Plankton in a given layer of surface water is in direct relation to the quantity of nutritive matters dissolved in that layer. Thus the actual quantity present of the substance—carbon, nitrogen, silica, or whatever it may be—that is first used up determines the quantity of the Phyto-Plankton. Nathansohn in a recent paper* contends that what Brandt

* "Monaco Bulletin," No. 140.

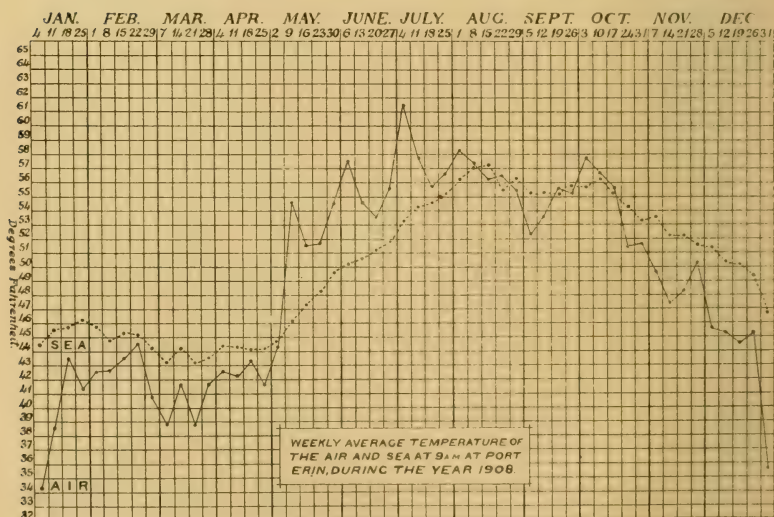
supposes never really happens; that the Phyto-Plankton never exhausts any food constituent, and that it develops just such a rate of reproduction as will compensate for the destruction to which it is subjected. This destruction he holds is due to two causes: currents carrying the Diatoms to unfavourable zones or localities, and the animals of the Plankton which feed on them. The quantity of Phyto-Plankton present in a sea will then depend upon the balancing of the two antagonistic processes—the reproduction of the Diatoms and their destruction. We require further knowledge in regard to their rate of reproduction and the amount of the destruction; but it has been calculated that one of these minute forms, less than the head of a pin, dividing into two at its normal rate of five times in the day, would at the end of a month form a mass of living matter a million times as big as the sun. The destruction that keeps such a rate of reproduction in check must be equally astonishing. It is claimed that the "Valdivia" results, and observations made since, show that the most abundant Plankton is where the surface water is mixed with deeper layers by rising currents. Nathansohn, while finding that the hour of the day has no effect on his results, considers that the development of the Phyto-Plankton corresponds closely with evidence of vertical circulation. Like some other workers, he emphasises the necessity of continuous intensive work in one locality. The "Challenger" and other great exploring expeditions forty years ago opened up problems of oceanography, but such work from vessels passing rapidly from place to place could not solve our present problems—the future lies with the naturalists at biological stations working continuously in the same locality the year round. As an example of the complexity of such problems, there seem to be two kinds of Diatom maxima found by

Nathansohn in the Mediterranean, one of *Chaetoceros* due to the afflux of water from the coast, and one of *Rhizosolenia calcar-avis*, due to a vertical circulation bringing up deeper layers of water.

The same principles and series of facts could be illustrated from the inland waters. Lakes periodically show Plankton maxima, which must be of vast importance in nourishing animals, and eventually the fishes used by man. Geologists have shown that Manitoba was in post-glacial times occupied by the vast lake Agassiz, with an estimated area of 110,000 square miles; and while the sediments of the extinct lake form now the celebrated wheat fields, supplying food to the nations, the shrunken remains of the water still yield, it is said, the greatest fresh-water fisheries in the world. It is to be hoped that nothing will be done further to reduce this valuable source of food. It is said that the Illinois fisheries yield at the rate of a pound a day throughout the year of cheap and desirable food to about 80,000 people—equivalent to one meal of fish a day for a quarter of a million people. The Canadian whitefish alone has yielded, I see, in recent years over 5,000,000 lbs. in a year, and all scientific men who have considered fishery questions will note with approval that all the fishing operations are now carried on under the regulations of the Dominion Government, and that fish hatcheries have been established on several of the great lakes which will, along with the necessary restrictions, form, it may be hoped, an effective safeguard against depletion. Much still remains to be done, however, in the way of detailed investigation and scientific exploitation. It has been shown in European seas that the mass of living food matters produced from the uncultivated water may equal that yielded by cultivated land. When aquiculture is as scientific as agriculture the

regulated and cultivated waters of North America, both inland and marine, may prove to be more productive even than the great wheat lands of Manitoba.

Inland waters may be put to many uses; sometimes they are utilised as sewage outlets for great cities, sometimes they are converted into commercial highways, or they may become restricted because of the reclamation of fertile bottom lands. All these may be good and necessary developments, or any one of them may be obviously best under the circumstances, but due regard should always be paid to the importance and promise of natural waters as a perpetual source of cheap and healthful food to the people of the country.



The above curves show the result of the temperature observations taken at the Biological Station during 1908, the last complete year. They show very clearly how the temperature of the sea (dotted) lags behind that of the air (whole lines), being higher in winter and lower in the height of summer.

L.M.B.C. Memoirs.

During 1909 no less than three Memoirs have been issued:—No. XVII, Pecten (the Scallop), by Mr. W. J. Dakin, M.Sc.; No. XVIII, Eledone (the local "Octopus"), by Miss A. Isgrove, M.Sc.; and No. XIX, on Polychaet Larvæ (the young stages of the Higher Worms) at Port Erin, by Mr. F. H. Gravely, M.Sc. Doris, the sea-lemon, by Sir Charles Eliot, and other Memoirs are also far advanced; and we hope to have a Memoir on our Irish Sea species of Ceratium and other Dinoflagellata from Prof. C. A. Kofoid, who did some work on our local material during his visit to our laboratory in 1908. This unusual amount of excellent material, which the Committee is happy to be able to issue to the scientific world, is, however, embarrassing from the point of view of expense. Lithographic plates, such as these Memoirs require, seem to become more costly, and with the growing elaboration of the subject more detailed illustration is necessary. The Committee are therefore always very grateful for special donations and grants which have in the past enabled the Treasurer to meet the expenses of plates for several of the above-mentioned Memoirs. Further donations to provide for the illustrations of those still unpublished will be very welcome.

The following shows a list of the Memoirs already published or arranged for:—

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.
II. Cardium, J. Johnstone, 92 pp., 7 Pls.
III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.
IV. Codium, R. J. H. Gibson and H. Auld, 3 Pls.
V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.
VI. Lepeophtheirus and Lernæa, A. Scott, 5 Pls.
VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.

VIII. Plaice, F. J. Cole and J. Johnstone, 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.
XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 144 pp., 9 Pls.
XVIII. Eledone, A. Isgrove, 113 pp., 10 Pls.
XIX. Polychaet Larvæ, F. H. Gravely, 79 pp., 4 Pls.
Doris, Sir Charles Eliot.
Cucumaria, E. Hindle.
Oyster, W. A. Herdman and J. T. Jenkins.
Ostracod (Cythere), Andrew Scott.
Buccinum, W. B. Randles.
Bugula, Laura R. Thornely.
Sagitta, E. J. W. Harvey.
Zostera, R. J. Harvey Gibson.
Himanthalia, F. J. Lewis.
Diatoms, F. E. Weiss.
Fucus, J. B. Farmer.
Botrylloides, W. A. Herdman.
Actinia, J. A. Clubb.
Hydroid, E. T. Browne.
Halichondria and Sycon, A. Dendy.
Sabellaria, A. T. Watson.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Pagurus*, *Pontobdella*, a Cestode and a Pycnogonid.

We append to this Report:—

(A) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations;

(B) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet.

Appendix A.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1909).

His Excellency the Right Hon. Lord Raglan, Lieut.-Governor of the Isle of Man.

Rt. Hon. Sir John Brunner, Bart., M.P.

Prof. R. J. Harvey Gibson, M.A., F.L.S., Liverpool.

Mr. W. J. Halls, Liverpool.

Prof. W. A. Herdman, D.Sc., F.R.S., F.L.S., Liverpool, Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

Dr. W. E. Hoyle, M.A., Museum, Cardiff.

Mr. P. M. C. Kermode, Ramsey, Isle of Man.

The late Mr. Joseph Lomas, Liverpool.

Sir Charles Petrie, Liverpool.

Mr. E. Thompson, Liverpool, Hon. Treasurer.

Mr. A. O. Walker, F.L.S., J.P., formerly of Chester.

Mr. Arnold T. Watson, F.L.S., Sheffield.

Curator of the Station—Mr. H. C. Chadwick, A.L.S.

Assistant—Mr. T. N. Cregeen.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The Committee shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the Affairs of the Committee shall be conducted by an Hon. Director, who shall be Chairman of the Committee, and an Hon. Treasurer, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any Vacancies on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The Expenses of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The Biological Station shall be used primarily for the Exploring work of the Committee, and the Specimens collected shall, so far as is necessary, be

placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

Laboratory Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and

Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

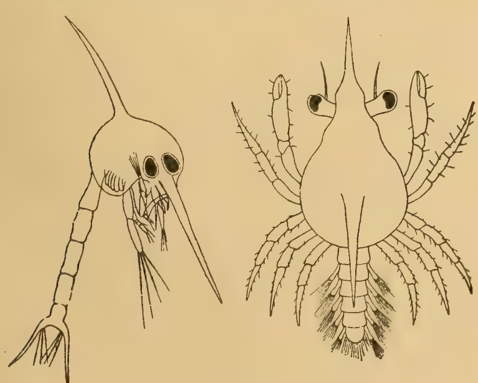
VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the

Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.



Young Crabs (Zoëa and Megalopa stages)—enlarged.

Appendix B.

HON. TREASURER'S STATEMENT.

As usual the financial statement for the year is shown in the few following pages.

Three new L.M.B.C. Memoirs have been published during the year, namely, Pecten (the common scallop), Eledone (an octoped cuttle fish) and Polychaet Larvæ. The two former are illustrated with finely lithographed plates, and the cost of producing them is necessarily great. Nineteen Memoirs have already been issued and there are more in course of preparation. Doris by Sir Charles Eliot is already far advanced, and it is hoped that Zostera, Sagitta, Buccinum and the Oyster will follow soon.

Unless more funds are forthcoming the publication of these Memoirs will have to be delayed, and the Treasurer hopes that further donations will be received to meet their cost. The Aquarium at Port Erin continues to prove a source of great interest to visitors to the Isle of Man, but owing to the bad season it is to be regretted that the present receipts do not quite equal those of last year.

The expenses of the Biological Station annually grow heavier, the work done there being continually on the increase as is shown in this Report. More subscribers are badly needed, and the Treasurer hopes that those interested in the work carried on by the L.M.B.C. will do what they can to help to increase the list.

Edwin Thompson,
Hon. Treasurer.

1, Croxteth Grove,
Liverpool.
December, 1909.

SUBSCRIBERS.

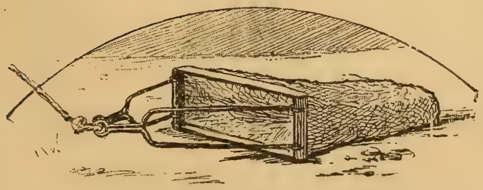
	£	s.	d.
Beaumont, W. I., Citadel Hill, Plymouth ...	1	1	0
Briscoe, F. W., Colby, Isle of Man	0	10	6
Brown, Prof. J. Campbell, University, Liverpool..	1	1	0
Browne, Edward T., B.A., 141, Uxbridge-road, Shepherd's Bush, London	1	1	0
Boyce, Sir Rubert, F.R.S., University, Liverpool	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, Sir John, Bart., M.P., Silverlands, Chertsey	5	0	0
Brunner, J. F. L., M.P. 23, Weatherley Gardens, London, S.W.	2	2	0
Bullen, Rev. R. Ashington, Heathside-road, Woking	1	1	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, J. A., Dr., Public Museums, Liverpool ...	0	10	6
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	6
Crosfield, Harold G., Fulwood-park, Liverpool ...	1	1	0
Dale, Vice-Chancellor, University, Liverpool ...	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Eliot, Sir Charles, University, Sheffield	1	1	0
Ellis, R. Williams, Chwilog, N. Wales	1	1	0
Gaskell, Holbrook, J.P., the late, Woolton Wood...	1	1	0
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Headley, F. W., Haileybury College, Hertford ...	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	1	1	0
Holt, Alfred, Crofton, Aigburth, Liverpool ..	2	2	0
Holt, Alfred, Dr., Crofton, Aigburth, Liverpool ...	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park, Liverpool	1	1	0
Forward	£36	19	6

	£	s.	d.
Forward... ...	36	19	6
Hoyle, Dr. W. E., Museum, Cardiff	1	1	0
Isle of Man Natural History Society	2	2	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Lever, W. H., M.P., Thornton Hough, Cheshire	1	1	0
Lewis, Dr. W. B., W. Riding Asylum, Wakefield...	1	1	0
Livingston, Charles, 16, Brunswick-st., Liverpool	1	1	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., 4, Oldhall-street, Liverpool...	0	10	0
Mond, R., Sevenoaks, Kent...	5	0	0
Monks, F. W., Warrington...	2	2	0
Muspratt, E. K., Dr., Seaforth Hall, Liverpool ...	5	0	0
Narramore, W., Cambridge Avenue, Great Crosby	1	1	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Petrie, Sir Charles, Devonshire-road, Liverpool...	1	1	0
Rae, Edward, Courthill, Birkenhead	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ...	1	1	0
Rathbone, Miss May, Northumberland-street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton, Liverpool	2	0	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	0
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Simpson, J. Hope, Ivy lodge, Aigburth, Liverpool	0	10	6
Smith, A. T., 43, Castle-street, Liverpool... ...	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson & Capper, 4, Lord-street, Liverpool ...	1	1	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Timmis, T. Sutton, Cleveley, Allerton	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Watson, A. T., Tapton-crescent, Sheffield... ...	1	1	0
Forward	£83	0	0

		£	s.	d.
Forward		83	0	0
Whitley, E., Clovelly, Sefton-park, Liverpool ...		2	2	0
Weiss, Prof. F. E., University, Manchester ...		1	1	0
Wiglesworth, Dr., Rainhill...		1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man		1	1	0
Yates, Harry, Shudehill, Manchester		1	1	0
		£89	6	0
Less				
Subscriptions paid in 1908	£1 11 6			
Do. unpaid	9 19 6	11	11	0
		£77	15	0
Add				
1908 Subscriptions received	£4 4 0			
1910 do. do.	1 1 0	5	5	0
		£83	0	0

Subscriptions for the Hire of "Work-Tables."

Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
	£30	0	0



The Naturalist's Dredge.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER. **Cr.**

1909.	£	s.	d.
To Printing and Stationery	1	11	8
,, Printing Memoirs	66	8	8
,, Plates for Memoirs	43	7	0
,, Boat Hire	7	13	0
,, Books and Apparatus at Port Erin Biological Station	23	8	2
,, Postage, Carriage, &c.	6	17	1
,, Natural History Specimens	0	7	2
,, Salary—Share of Curator's	75	0	0
,, ,, ,, Assistant's	27	6	0
,, Sundries	10	0	0
,, Balance in hand December, 1909	1	12	8
	£263	11	5

EDWIN THOMPSON,
HON. TREASURER.

LIVERPOOL, *December 18th, 1909.*

1909.	£	s.	d.
By Balance in hand December, 1908	18	5	0
,, Subscriptions and Donations received	83	0	0
,, Amount received from Universities for hire of "Work Tables"	30	0	0
,, Sale of Specimens, Bottles, &c,	3	5	10
,, Interest on British Association (1896) Fund	37	16	8
,, Bank Interest	1	19	10
,, Laboratory and Class Fees	3	10	0
,, Sale of Guides	6	10	0
,, Sale of Publications	3	16	6
,, Admissions to Aquarium	16	19	4
,, Sale of Memoirs	23	8	3
,, Amount transferred from Memoir Fund	35	0	0
	£263	11	5

Endowed Invested Fund:—
British Workman's Public House Co.'s Shares ... £173 1 0

Memoir Fund—Balance in Bank ... £79 6 0

Audited and found correct,
COOK & LEATHER,
Chartered Accountants.

REPORT on the INVESTIGATIONS carried on during 1909 in connection with the LANCASHIRE SEA-FISHERIES LABORATORY at the University of Liverpool, and the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary Director of the Scientific Work; assisted by Mr. ANDREW SCOTT, A.L.S., Resident Fisheries Assistant at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries Assistant at the Liverpool Laboratory.

(With plates and text figures.)

CONTENTS.

INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

In presenting this Annual Report (the 18th of the series) upon our scientific work to the Committee, I wish, as usual, to make a few comments upon the more special and detailed articles that follow, and to call attention to any matters in the present condition of sea-fisheries research to which the special notice of the Committee should be directed.

When the last Report was published the organisa-

tion, equipment and work of our scientific department had just been reported upon very fully by the Treasury Committee which sat two years ago under the chairmanship of Mr. H. J. Tennant, M.P. I think it may be said that our arrangements generally were approved of, and that it was felt by the Committee of Enquiry that local effort on the West coast was worthy of recognition and Government support. No action has, as yet, been taken upon the report of Mr. Tennant's Committee.

A change of considerable importance is, however, at present being brought about in the organisation and direction of official sea-fisheries research in this country, which it is to be hoped may lead to the West coast receiving in the near future somewhat the same measure of recognition and financial support as has been given during the last decade to similar scientific fisheries work on the eastern and the southern coasts of England.

It is to be hoped that before long under the new auspices a detailed survey of our British fishing grounds, and of all waters within the territorial area, will be undertaken, and it is essential that such work at sea as has been carried on of late—for example, by our own Committee in the Irish Sea—should be continued, and even increased and improved. Almost every department of our work requires further financial support. We require a Naturalist to take charge of the observational work on the "James Fletcher," and we require a Chemical Assistant to carry on the investigations which have been so kindly undertaken for us in the past by Dr. Bassett. A more detailed statement of the existing laboratory and other scientific equipment for sea-fisheries investigation, now available for public service on the shores of the Irish Sea, was given in the Introduction to our last Report, and need not now be repeated.

Work at Piel.

Mr. Scott supplies his usual short article giving the results of the fish hatching at Piel during the past season. There is no change to record. The apparatus and the supply of adult fish is the same as it has been for some years, and the total number of young flat fish set free, nearly $13\frac{1}{2}$ millions, is practically the same as on several former occasions. The spawning in the Piel hatchery appears to take place definitely a little later in the season than that at Port Erin in the Isle of Man. I may remind the Committee that at the Port Erin hatchery last season over seven millions of young plaice were successfully hatched and set free in the open sea. Both Fisheries Authorities—that of Lancashire and that of the Isle of Man—are to be congratulated on the co-operation of the other in thus adding to the available stock of young flat fish on the common fishing grounds.

The four usual classes for fishermen were held this year, thus enabling 45 men in the administrative county, besides 13 others, to attend the instruction given by Mr. Johnstone and Mr. Scott at the Piel Laboratory. A change was made this year in regard to the fourth class whereby, with the co-operation of the Lancashire Education Committee, some instruction in Navigation as applied to fishing vessels was given to a set of men working on the Fleetwood trawlers with, it is said, very satisfactory results. It is gratifying to learn that a number of the students subsequently passed their Board of Trade examinations, and the experiment of providing this instruction in connection with the marine biology classes will probably be repeated.

A considerable part of Mr. Scott's time not required for routine official duties, such as the fish hatching and

the fishermen's classes, has been occupied in working out the microscopic quantitative results of the plankton collections made by myself and others from the seas to the South and West of the Isle of Man, and this work is again, as in the last two years, incorporated in our joint paper on "Intensive Study of the Plankton" (Part III.) which will be found at the end of the Report.

Mr. Scott has further devoted some time to the examination of the shell-fish beds of his neighbourhood, and I have re-printed a short report on the Flookburgh cockle-beds which he drew up for our last Quarterly Report to the Scientific Sub-Committee.

Mr. Johnstone has carried on his work partly at Piel, partly at sea, and partly in the Liverpool laboratory, and his results will be seen in several of the articles in this Report. He has continued his work on the internal parasites of some of our local fishes—such as the Skate—and this forms the subject of one of the papers below.

Measurements of Plaice.

One of the most extensive articles in this Report is an account by Mr. Johnstone of the measurements of many thousands of Irish Sea plaice which have been made by our staff at sea during the last couple of years. The object of this investigation is to get information with respect to the sizes of the plaice inhabiting the various fishing grounds in the district. The results of the trawling experiments and the statistics recorded in the past are not sufficiently exact and definite, so far as the size of the fish caught is concerned, to be of much value. This gap in our knowledge is now being filled up, and the statistics obtained during the last two years include individual measurements of nearly 100,000 plaice.

In the summary of this work which Mr. Johnstone

gave in the last Quarterly Report, he directed attention to the following points:—

(1) The prevalent, or *modal*, lengths of the plaice taken month by month on the various grounds by means of a 6-inch trawl net. Those from Rock Channel, in the Mersey, were the smallest by far, and those from Red Wharf Bay, in December, were the largest, with the exception of some catches made off New Quay, in Cardigan Bay. The percentages of fish of each length, in centimetres, are given in the Report. The lengths in inches can be obtained by dividing the lengths in centimetres by $2\frac{1}{2}$.

(2) The variation in length from month to month.

(3) The variation in "condition" from month to month, and on the various fishing grounds. As a rule the condition was worst, in the case of immature fish, in January and February, and best in July and August.

(4) The small percentage of sexually mature, or spawning, fishes taken in inshore waters—except in Luce Bay, and in the Firth of Clyde.

(5) The ages of the fish, the great majority of the plaice in the inshore grounds off the West Coast of England and Wales being less than three years old.

(6) The influence of the size of the trawl-net mesh. In spite of the enormous numbers of small plaice taken by the 6-inch trawl mesh in some areas, like Rock Channel for instance, there is no clear evidence for the conclusion that the 6-inch mesh is wastefully destructive. The plaice are small, and are below the normal in "condition" because they are so abundant. If they could be "thinned out" by transplantation it might be of advantage to the fisheries in general to enforce the 7-inch mesh. But so long as they cannot be transplanted, it is open to doubt whether the use of the larger mesh would lead to any

improvement, and it would certainly diminish the takings of the inshore fishermen.

Future investigations may, however, lead one to modify this opinion. If, after several years' employment of the 6-inch net, the plaice were, on the whole, to become smaller, the continued use of the latter net might be held to be injurious to the fisheries. The present investigations ought therefore to be continued, and no doubt will be. The results obtained are bound to be of value in relation to regulations of the trawl-net mesh.

It is pleasant to record that this work of the measurement of the plaice captured has been conscientiously and carefully carried out by Capt. Wignall and his Officers, and by the Bailiffs in charge of the districts.

Hydrography.

As on former occasions, Dr. Bassett, of the University Chemical Department, has very kindly taken the trouble to examine our samples of sea-water and report upon their salinity. Dr. Bassett contributes two articles to this Report, and in the first of these he discusses the main results obtained from the periodic hydrographic cruises made during 1909; while Mr. Johnstone in the next paper gives an account of the temperature observations made on the same cruises, and from some other data. The effect of the distribution of temperature and salinity upon the movements of fishes in our seas is still to be determined, and such papers as those now presented by Dr. Bassett and Mr. Johnstone are important contributions to the subject. The accord which Dr. Bassett points out between the hydrographic observations and the general weather conditions of the British Islands is most interesting. He concludes with the hypothesis that "the peculiar weather

of the last year is directly traceable to the late arrival of the Gulf Stream Drift, coupled with its unusually low temperature (due probably to greater admixture with Arctic water of low salinity)"; and bases upon this the proposition that, after further work, it may prove possible to predict the general character of the summer and autumn of any year from hydrographic observations made during February and March in the Irish Sea and English Channel, and similarly the probable nature of the succeeding winter, from observations made during the summer.

In his second paper, Dr. Bassett discusses fully the view which he had referred to in former reports that there is a flow of water from South to North through the Irish Sea. He points out that some writers on hydrographical conditions in British seas seem to think that exactly the reverse current exists; and then he gives his data leading to the conclusion that, without any doubt, the water does actually flow from South to North through the Irish Sea as a whole—the current passing to the East of the Isle of Man.

Plankton.

My own contribution to this Report is the result of almost continuous daily work at sea during the Easter and a part of the summer vacation, testing plankton nets and other apparatus, and collecting samples of the organisms in the sea-water, along with samples of the water at various depths and sea-temperatures. This work was carried on from Port Erin as a centre, out to the middle of the Channel between Ireland and the Isle of Man and down to depths of 76 faths. In this work at sea, and also in the subsequent laboratory work ashore, I have

been ably assisted by Mr. W. J. Dakin and Mr. William Riddell. The results obtained will be found in Part III of the Plankton paper at the end of this Report.

Shellfish and Pollution.

The state of the law in regard to the pollution of shell-fish beds by sewage is still a menace to the public health and a reproach to civilisation. The necessary legislative reform will no doubt come sooner or later; but if the Sea-Fisheries Local Authorities can do anything further to secure more immediate attention to the evil and to insure its removal this year or next year in place of a decade hence, their action will deserve the gratitude of the community they represent and will receive the approval of posterity.

W. A. Herdman.

Fisheries Laboratory,
University of Liverpool,
March 15*th,* 1910.

FISH HATCHING AT PIEL.

By Andrew Scott.

The results from the fish hatching conducted in the Spring of 1909 were almost similar to those obtained in 1907 and 1908. The maturing plaice were collected in the closed area of Luce Bay by our Fisheries steamer S.S. "James Fletcher," and we are very much indebted to the Fishery Board for Scotland for granting us permission to trawl in this protected fishing ground each year. It ensures that a supply of adult plaice will be secured in a very limited time, and consequently they can be conveyed to Piel under the most favourable conditions. Without such a privilege it would be almost impossible to get satisfactory fish; at any rate, it would necessitate spending several days at sea trawling in all directions, and consequently the captured fish would be landed in a very exhausted condition. The parent flounders were caught in the vicinity of Piel, as usual, by the police cutter stationed in the northern division of the Lancashire district.

The fish commenced to spawn on March 4th, and the first fertilised eggs were obtained five days later. The spawning lasted for two months. During that time one million four hundred thousand plaice eggs were obtained, and thirteen million eight hundred thousand flounder eggs. The incubation of the eggs was carried out in the Dannevig hatching apparatus, and the resulting fry were afterwards liberated in the sea. The parent fish were set free in the channel adjoining the establishment.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified:—

PLAICE (*Pleuronectes platessa,* Linn.).

			Eggs Collected.	Fry Set Free.			
March	9	...	20,000	17,500	...	March	26
,,	12	...	30,000	26,000	...	,,	,,
,,	15	...	45,000	40,000	...	,,	31
,,	17	...	50,000	44,000	...	,,	,,
,,	19	...	65,000	57,500	...	,,	,,
,,	22	...	70,000	62,000	...	April	6
,,	24	...	75,000	66,500	...	,,	,,
,,	26	...	80,000	70,000	...	,,	,,
,,	28	...	80,000	70,000	...	,,	12
,,	30	...	85,000	75,000	...	,,	,,
April	1	...	90,000	79,000	...	,,	,,
,,	3	...	95,000	84,500	...	,,	19
,,	6	...	95,000	84,500	...	,,	,,
,,	8	...	90,000	79,000	...	,,	,,
,,	12	...	85,000	75,000	...	,,	24
,,	14	...	80,000	70,000	...	,,	,,
,,	16	...	75,000	66,500	...	,,	30
,,	19	...	60,000	51,500	...	,,	,,
,,	21	...	55,000	47,500	...	May	14
,,	26	...	40,000	34,500	...	,,	,,
,,	30	...	25,000	22,000	...	,,	22
May	5	...	10,000	8,500	...	,,	,,
Total Eggs			1,400,000	1,231,000	Total Fry.		

FLOUNDER (*Pleuronectes flesus*, Linn.).

		Eggs Collected.	Fry Set Free.	
March	9	... 150,000	133,000 ...	March 31
,,	12	... 200,000	177,000 ...	,, ,,
,,	15	... 350,000	300,000 ...	April 6
,,	17	... 450,000	400,000 ...	,, ,,
,,	19	... 650,000	580,000 ...	,, ,,
,,	22	... 650,000	580,000 ...	,, 12
,,	24	... 700,000	600,000 ...	,, ,,
,,	26	... 800,000	712,000 ...	,, ,,
,,	28	... 850,000	757,000 ...	,, 19
,,	30	... 950,000	846,000 ...	,, ,,
April	1	... 950,000	846,000 ...	,, ,,
,,	3	... 1,000,000	887,000 ...	,, 24
,,	6	... 900,000	800,000 ...	,, ,,
,,	8	... 900,000	800,000 ...	,, ,,
,,	12	... 900,000	800,000 ...	,, 30
,,	14	... 850,000	757,000 ...	,, ,,
,,	16	... 650,000	580,000 ...	,, ,,
,,	19	... 600,000	530,000 ...	May 14
,,	21	... 450,000	400,000 ...	,, ,,
,,	26	... 350,000	300,000 ...	,, ,,
,,	30	... 350,000	300,000 ...	,, 22
May	5	... 150,000	133,000 ...	,, ,,
Total Eggs		13,800,000	12,218,000	Total Fry.

Total Number of Eggs 15,200,000

Total Number of Fry 13,449,000

CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott.

Four classes for fishermen were held in the Spring of 1909. The Education Committee of the Lancashire County Council voted the usual money grant, which enabled forty-five fishermen residing in the administrative County to receive studentships and attend a course of instruction at the Piel Marine Laboratory. The Cheshire Education Committee sent four men, and the Southport Education Committee also sent four. The Blackpool Education Committee again sent three men. The Education Committee of Birkenhead sent two Tranmere fishermen. Altogether fifty-eight men attended the classes and received instruction in elementary Marine Biology. The studentship holders were divided into four classes—three of fifteen each, and one of thirteen, as shown by the following lists:—

First Class, held March 8th to 19th.—John Hutton, Flookburgh; Richard Stackhouse, Bolton-le-Sands; John Willacy, Morecambe; John Mount, Morecambe; Samuel Baxter, Morecambe; Jas. Wm. Gardner, Sunderland Point; William Parkinson, Blackpool; Richard Cornall, Blackpool; R. Westhead, Blackpool; Alfred Whiteside, Lytham; George Henry Oxley, Lytham; Thomas Wareing, Banks; Paul Wareing, Banks; John Kay, Tranmere; Arthur Shaw, Lower Tranmere.

Second Class, held March 22nd to April 2nd.—Harry Procter, Askam; John Thompson, Roosebeck; William Bayliff, Baycliff; John Relph, Ulverston; Michael Johnson, Ulverston; W. Benson, Flookburgh; Edward Burrow, Flookburgh; Adam Woodhouse, Morecambe; Samuel Houghton, Morecambe; John Cocking, Morecambe; John Hadwen, Morecambe; Edward Ainsworth,

Knott End, Fleetwood; William Parkinson, Hambleton; James Aughton, Banks; Richard Johnson, Banks.

Third Class, held April 19th to 30th.—Thomas Cocking, Morecambe; Walter Hadwen, Morecambe; Johnson Raby, Morecambe; Thomas Woodhouse, Morecambe; Richard Laytham, Lower Heysham; William Leadbetter, Junr., Banks; William Bridge, Junr., Banks; Peter Wright, Southport; Geoffrey Wright, Southport; William Southworth, Southport; Thomas Halsall, Southport; James Murray, Egremont; William Cross, New Brighton; Thomas Matthews, Junr., Neston; William Mealor, Junr., Parkgate.

Fourth Class, held May 3rd to 14th.—William Annison, Thomas Bailey, Edward Colley, Thomas Colley, P. W. Jennings, James Wilson Meadows, Charles Radford, Horace Ross, William Roskell, Arthur Suker, James Sumner, Thomas Whalley, G. Wilson—Fleetwood.

The course of instruction given hitherto in the fishermen's classes has been mainly in general Marine Biology, with special reference to the structure, life and habits of the more important fish and shellfish. The Scientific Sub-Committee, with the co-operation of the Lancashire Education Committee, decided that an attempt should be made in one of the classes held during the Spring of 1909 to combine the course of Marine Biology with instruction in navigation as applied to fishing vessels. The fourth class of the series was therefore made a special one, and was attended by fishermen employed on trawlers working out of Fleetwood. Preference was given to men possessing the necessary qualifications in deep sea fishing vessels which enabled them to sit for the Board of Trade examinations for certificates as second hand or skipper of a fishing vessel. The first lesson of each day was confined to general

Marine Biology, and was conducted in the usual manner. The County Navigation Instructor took charge of the class in the afternoons, and two lessons were given each day in navigation, viz., 1.30 to 3.30 p.m. and 5 to 6 p.m. The results of the experiment appeared to be quite satisfactory, and a number of the students passed at the Board of Trade examinations held at Fleetwood shortly after the classes terminated.

The usual thanks to the Sea-Fisheries Committee and to the various Educational Committees, were proposed and carried by the fishermen at each class.

One class in Nature Study for school teachers was conducted during the months of April and May. The class was organised by the Barrow Education Committee, and was attended by teachers belonging to their schools. The course of instruction was the same as that mentioned in the Annual Report for 1907.

Dr. Das, on behalf of the Bengal Government, visited the establishment early in March. Dr. H. T. Bulstrode, Medical Officer to the Local Government Board, made an inspection of the various sewage outfalls in the district and visited the Laboratory in March. I accompanied him in his survey of the Barrow outfall, and of the course of the effluent along the shore of the channel.

A large party of Members of the Lancashire Sea-Fisheries Committee and of the various Educational Committees of the County, visited the establishment and saw the fishermen at work. Short addresses to the men were given by the visitors. The party was organised by Mr. James Fletcher, but he was unfortunately unable to be present. The members of the St. Matthew's Mutual Improvement Society visited the Laboratory during the Easter Holidays. Mr. A. Harris, one of H. M. Inspectors of Evening Schools, visited the classes for the purpose of

reporting on the work. Dr. H. L. Snape, Director of Education to the Lancashire County Council, visited the Navigation Class.

A number of interesting Memoirs of the Indian Museum have recently been presented to the Library at Piel by Dr. Annandale, the Superintendent of the Indian Museum, Mr. E. W. L. Holt, the Scientific Adviser to the Irish Fisheries Department, has, as usual, sent numerous reprints of papers from the Reports on the Sea and Inland Fisheries of Ireland. The United States Fisheries Department, the Smithsonian Institution, the Trustees of the British Museum, &c., have also supplied valuable contributions to our stock of literature.

INTERNAL PARASITES OF FISHES FROM THE IRISH SEA.

By Jas Johnstone.

Contents.

(1) **Lebouria idonea,** Nicoll.*

Habitat: Intestine of *Callionymus lyra*, Morecambe Bay.

The present species is the type-form of a new genus proposed by Nicoll for the inclusion of a Trematode found by him very regularly, and in large numbers in the intestine of the Cat-fish, *Anarrhichas lupus*, and less frequently in the stomach. It is certainly rare in Irish Sea fishes, and I have only found one specimen so far in a Common Dragonet caught in the shrimp-trawl in Ulverston Channel, in Morecambe Bay.

Measurements of the specimen are as follows:—

Length: 0·87 mm.
Breadth: 0·39 mm.
Transverse diameter of oral sucker: 0·13 mm.
,, ,, ,, ventral sucker: 0·3 mm.

Nicoll's specimens varied from 1·5 to 2·5 mm. in length and from 0·7 to 1·0 mm. in breadth, and are therefore considerably larger than the specimen described here. There are also some other differences, but I think it very probable that the species is the same in both cases, my specimen being apparently immature.

* "Studies on the Digenetic Trematodes," *Quart. Journ. Microsc. Science*. Vol. LIII, Pt. 3, May, 1909, pp. 441-451; Pl. 9, fig. 9.

The worm is represented in fig. 1, p. 79. The preservation was not good, and there is evidently some distortion. Bearing this in mind there is a close similarity between my figure and Nicoll's. The oesophagus and intestinal rami were not seen. The anterior part of the animal is greatly contracted. so that the cirrus-pouch and vesicula seminalis, which lay immediately in front of the ventral sucker were not seen clearly enough to be figured.

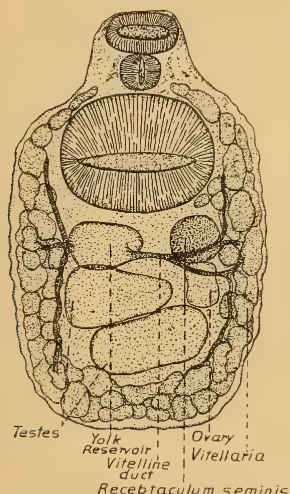


Fig. 1. *Lebouria idonea*, Nicoll. Mag. 63 dia.

The testes are very prominent and are placed about halfway between the posterior margin of the ventral sucker and the extremity of the body. They are elongated transversely and have very much the same proportions and appearance as in Nicoll's figure. The vitellaria are very conspicuous, more so than in Nicoll's specimens. They lie along each side of the body and behind the testes, with a few follicles extending in front of the ventral sucker. The vitelline ducts were also made out very clearly. The two efferent portions pass transversely towards the centre of the body,

at about the middle, and join to form a large yolk reservoir. This also is shown in Nicoll's figure, but the reservoir does not appear to have been as large in his specimens as in mine. The ovary and receptaculum seminis lie on the right side of the body in front of the testes. No trace of the uterus could be made out, but the specimen contains one egg lying apparently near the yolk reservoir. The diameters of this are 0·79 by 0·47 mm., almost exactly the sizes given by Nicoll for his type specimens.

(2) **Prosthecobothrium dujardinii,** (van Beneden).*

Habitat: large intestine of *Raja maculata*, Cardigan Bay.

This cestode is apparently very rare in Irish Sea fishes, and so far I have only seen one specimen. It is desirable to draw attention to some points in the anatomy of the species which do not seem to conform to the diagnosis of the genus. The species was described by van Beneden as *Acanthobothrium dujardinii* but was made the type of a new genus by Diesing†. The characters of the genus *Prosthecobothrium* thus formed are: Scolex with four undivided bothridia, each having a suctorial appendage at its posterior extremity; no accessory suckers on the anterior margins of the bothridia; two double hooks on each of the latter.

The measurements of the worm are:—

Length of strobila, about 10 mm.
No. of proglottides, about 6.
Length of scolex, 0·39 mm.
Length of hooks, 0·13 mm.
Length of longest proglottis, 2·12 mm
Breadth of ,, ,, 0·5 mm.

* "Faune littorale de Belgique: les Vers Cestoides." *Nouv. Mem. Acad. Roy. Belgique*, T. XXV, p. 133. Pl. X, 1850.

† "Revision der Cephalocotyleen." *Sitzungsber. Acad. Wiss. Wien; Math.-Nat.* cl.; Bd. 48, 49, 1864.

The scolex is represented in fig. 2. There are four very prominent bothridia each of which projects well out from the neck.

The latter is very short. There are no accessory suckers at the summits of the bothridia. Each of the latter is really divided into three loculi by two transverse, curved costae, but the most anterior loculus is long, about twice the length of the two posterior ones, and it is not apparently

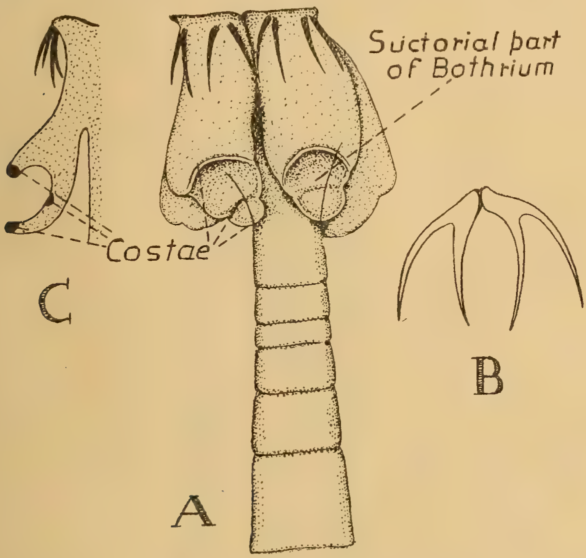


Fig. 2. *Prosthecobothrium dujardinii*, (van Beneden). A, the scolex; B, diagram of one bothrium, seen from the side; C, the hooks. A and C mag. 76 dia.; B mag. 154 dia.

concave transversely. The most anterior costa is very prominent, and the second one difficult to see. There appears to be only one loculus, but close examination shows that a costa is concealed in this deeply concave double loculus. This is shown in fig. 2 A, and the diagram, fig. 2 C. It forms a cup-shaped structure—the "appendice très-motile qui a la forme d'un feuille" of van Beneden.

The bothrium is thus essentially similar to that of

Acanthobothrium and differs in that the accessory suckers are absent. It is similar to the latter forms in that double hooks are present, one pair on each bothrium. The hooks are represented in fig. 2 B. Each consists of two long, slightly curved, slender spines fused together by their bases. This fused median part is not nearly so prominent

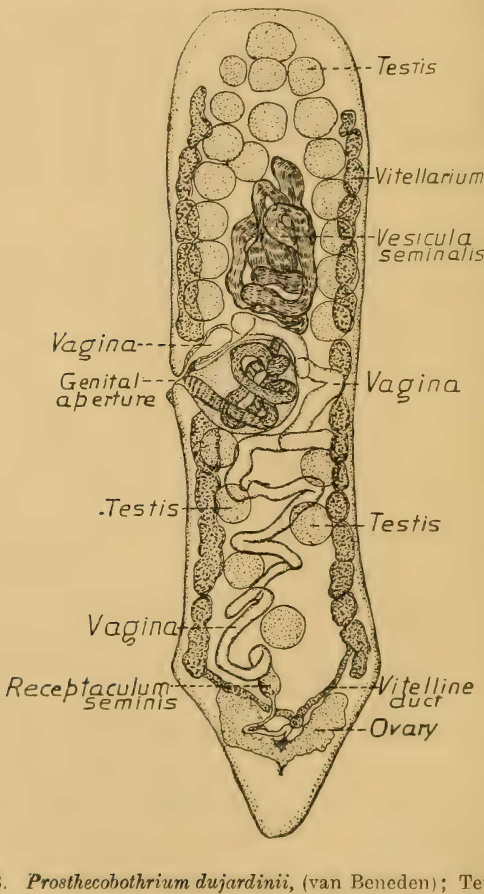


Fig. 3. ***Prosthecobothrium dujardinii***, (van Beneden); Terminal proglottis. Mag. 51 dia.

as is represented in van Beneden's figure. The hooks stand well out from the face of the bothrium.

The terminal proglottis—the only one in the strobila which was mature—is represented in fig. 3. The posterior

extremity is pointed and the ovary is situated here; it is a bi-lobed structure tapering to a point at its posterior margin. The oviduct and uterus were not well enough seen in the single preparation available to be figured. Probably they were insufficiently developed, and it is very likely that complete maturation of the female organs takes place in this, as in so many other tapeworms, after the proglottis has dehisced from the strobila and is free in the alimentary canal of the host. Perhaps there may have been free proglottides in this particular fish, but they were not identified. The vitellaria form two bands of follicles distributed along the margins of the proglottis, and the ducts pass off from their posterior extremities and run obliquely backwards, joining to form a small yolk reservoir.

The testes are about 24 in number and lie mainly on the lateral parts of the proglottis, but a few are distributed in the median regions of the latter; they are comparatively large spherical bodies. The cirrus-pouch is very large and is almost exactly median; within it is a comparatively long cirrus, armed with short, blunt, straight spines for the most of its length. This is continuous with the vesicula seminalis which lies coiled up in a compact mass between the cirrus pouch and the anterior extremity of the proglottis.

The genital aperture is lateral and nearly half-way between the ends of the proglottis. There is a well-marked vagina, which is dilated terminally. The duct passes back, being coiled loosely towards the ovary. At its posterior extremity it is dilated to form a small receptaculum seminis, and from this a very narrow duct passes backwards towards the ovary. The junction of receptaculum seminis, oviduct and vitelline ducts was not seen.

Echeneibothrium, van Beneden.

A large number of specimens of cestodes belonging to this genus were obtained from various species of Ray during the present year, and it seems useful, in view of the great variability of character exhibited by the various species belonging to this group, to describe these worms in some detail. The genus *Echeneibothrium* is defined by the presence of four Echeneiform bothria carried on contractile pedicels; by the absence of any armature of the bothria; and by the presence of a contractile myzorhynchus, at the apex of which there is a terminal *os*.

(3) **Echeneibothrium variabile**, van Beneden.*

This is the typical species. The bothria, pedicels, and myzorhynchus are highly contractile, and very different appearances are presented by the worms when they die, and also according to the mode of preservation employed. I describe here two forms which appear very frequently in Irish Sea fishes.

I. Pear-shaped myzorhynchus, with terminal *os* leading to a concealed proboscis. Bothria typical in form and structure. Fig. 4, page 85, represents the appearance of the scolex of a specimen killed in fresh water and preserved in formalin. The worm was unstained and was examined in water. The measurements are :

Greatest diameter of the scolex: 1·24 mm.
Diameter of myzorhynchus: 0·58 mm.
Diameter of terminal *os*: 0·2 mm.

The bothria present the typical structure; they are leaf-shaped with eight or more transverse, and one longitudinal costae. Their apices are curled over, and in the bothrium at the lower right-hand corner of the figure, one of the lateral margins is also curled over. The scolex is

* "Vers cestoides," p. 113, Pl. III.

seen from the anterior end so that we look down through the *os*. Inside the latter the proboscis may be seen. It is partially divided and shows four distinct lobes.

Fig. 5, page 86, represents another scolex of the same type. The measurements are:—Width, 1·76 mm.; Length, 0·80 mm. The cestode was killed and preserved in the same manner as that just described. The pedicels are contracted to some extent and the bothria are also contracted, exhibiting a very typical cup-like contour. The myzorhynchus is flattened at the summit.

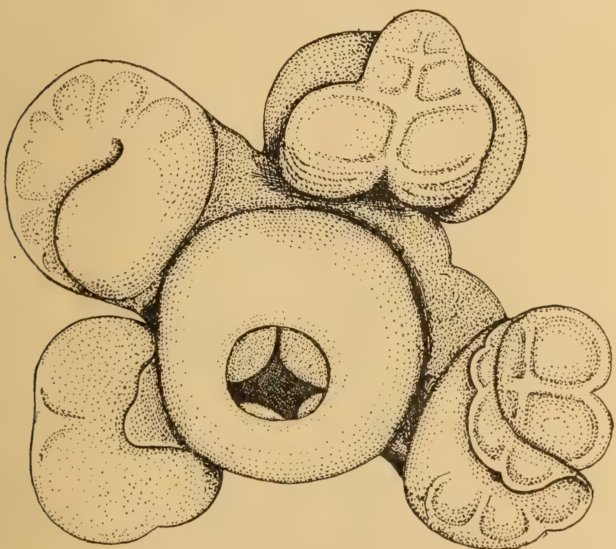


Fig. 4. *Echeneibothrium variabile*, van Beneden; Scolex seen from the anterior end. Mag. 60 dia.

Fig. 5 also represents another scolex of the same type. The worm was killed and preserved as before, but the bothria are contracted to a much greater degree than in the two other specimens. It has been stained with borax-carmine and cleared, and is drawn after it has been flattened out between the slide and cover-glass. It will be

seen that the terminal *os* in the myzorhynchus leads into a kind of atrium in which there is a proboscis. The latter is bowl-shaped, presenting very much the same appearance as the large ventral sucker in a Trematode. Its internal walls are not smooth, but are thrown into lobes by the contraction of the intrinsic and extrinsic musculature of

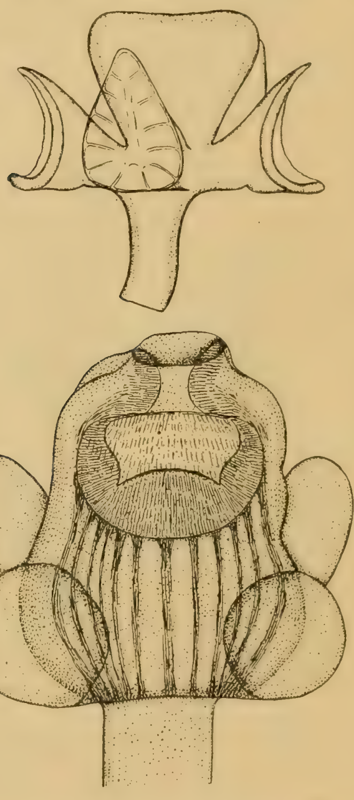


Fig. 5. ***Echeneibothrium variabile***, van Beneden; the upper figure is a general view of the scolex, the lower figure represents another scolex prepared to show the internal proboscis.

the structure. The wall of the myzorhynchus immediately round the *os* is strongly muscular, so much so that we may speak of the presence of a distinct sphincter; and there are also longitudinal muscle fibres passing back to their origins

in the basal part of the myzorhynchus. This terminal sphincter muscle lies on and round the opening of the proboscis, and it can evidently be contracted so as entirely to close the *os*. The figure also shows a series of muscles originating in the base of the myzorhynchus, and inserted into the sides of the proboscis. Evidently these must function as retractors of the latter structure.

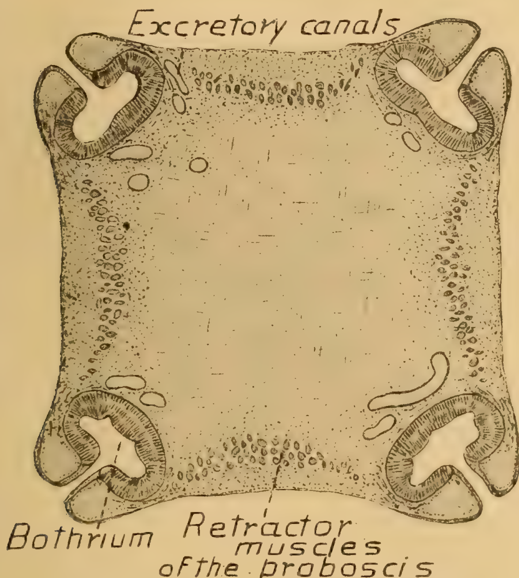


Fig. 6. *Echeneibothrium variabile,* van Beneden. Section of the scolex passing through the bothridia. Mag. 40 dia.

Fig. 6, page 87, represents a section of a scolex belonging to this variety of *E. variabile.* The plane is transverse and passes through the posterior part of the scolex, through the pedicels and openings of the bothria. The specimen was preserved in corrosive-sublimate alcohol, and the bothria are very much contracted until the openings

are reduced to narrow slits. In this region the greater part of the scolex consists of a fine fibrous connective tissue containing few muscle fibres running mostly at right-angles to each other from opposite sides of the scolex, which is nearly square in cross section at this plane. Between every two bothria there is a band of stout muscle-fibres; these are the fibres represented in surface view in fig. 5; they originate mostly at the junction of scolex and neck, but many are continuous with the longitudinal fibres in the latter part of the strobila. The canals shown in section near the bothria are part of the excretory channels. In the neck these mostly run axially, but at the base of the scolex they pass towards the bothria and run in the tissues of the latter organs.

Fig. 7, page 89, represents a transverse section of the scolex anterior to the plane of the section just described. It passes through the proboscis just anterior to the base of the latter. The internal wall is thick and fibrous, and next to this is a rather strong layer of muscle fibres running circularly. External to this are the radial fibres arranged just as in the ventral sucker of a Trematode. The external wall of the proboscis is also thickened and fibrous, and inserted into it, at nearly equal intervals, are strong muscle bundles. These are the retractors of the proboscis, and are the same structures as are represented in figs. 5 and 6. A few excretory canals are to be seen in the section. With the exception of the outer wall of the scolex which is rather thick, the remaining tissue is a loose connective stroma.

Anterior to the plane of this section the anterior lips of the proboscidial sucker are free from the internal walls of the atrium into which the *os* leads.

II. Myzorhynchus large and rosette-like and without a terminal *os*. Bothridia typical.

The presence of this complex myzorhynchus, and the variability of the shapes into which it may be thrown by the action of its muscles, often renders the identification of species of Echeneibothrium a difficult matter. It often happens that the terminal *os* cannot be seen, that the

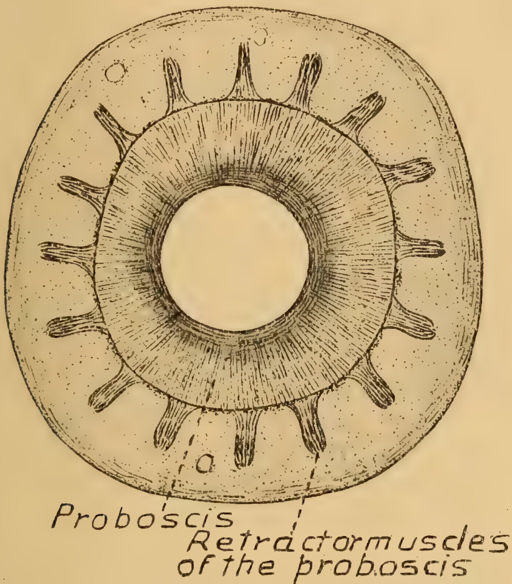


Fig. 7. *Echeneibothrium variabile*, van Beneden.
Section through myzorhynchus. Mag. 110 dia.

myzorhynchus is large, and flattened out in the transverse plane, while the bothridia and their pedicels may be very much contracted. These changes are without doubt caused by the eversion of the internal proboscidal sucker, and the reversal of the surfaces of the latter. Then the retractor muscles, pulling on the walls of the proboscis, throw the latter into lobe-shaped structures. This radial structure can often be seen when looking down on the surface of the myzorhynchus; it is shown, for instance, in fig. 4, p. 85,

and it is suggested in van Beneden's fig. 2, Pl. III.* Olsson† (Tab. I, fig. 15) also represents it very clearly and ascribes the condition to the real cause. [" Bulbus apice expanso (forma singularis floribus Rosarum similis)."]

Fig. 8 represents views of the scolex of an *E. variabile*, the anterior aspect of the myzorhynchus on the right and the posterior aspect on the left, the neck being bent at a right angle to the scolex. The myzorhynchus is nearly round in surface view and it is flattened

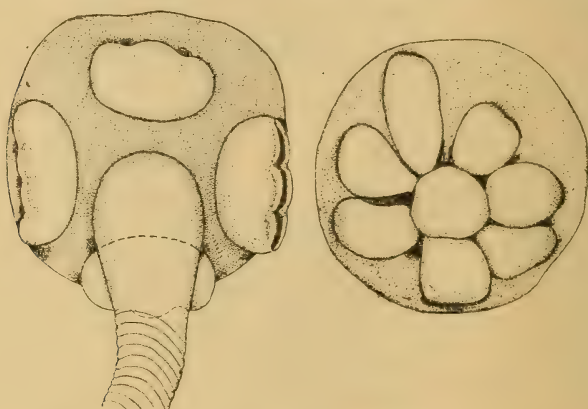


Fig. 8. ***Echeneibothrium variabile***, van Beneden: the left-hand figure represents a view of the scolex from beneath, on the right the scolex is seen from its anterior surface. Mag. about 35 dia.

greatly to form a disc; from this aspect the bothridia were quite invisible. On the anterior surface of the myzorhynchus were one central and six radially arranged lobes. These structures are very distinct and are raised up from the surface of the scolex, so that they can be seen when the latter is looked at from the side. But they are not free from the myzorhynchus, not even at their apices and in some cases the sulci between them are very shallow. In yet

* *Loc. cit.*

† *Acta Univers. Lundensis*; *Lunds. Univers. Aarskrift för* 1865; *Afd. Math.-Natur.* IV, Lund., 1866-7.

another cestode a somewhat similar condition was present, but the myzorhynchal lobes were asymmetrically arranged, there being a group of five small ones on one margin; at either end of this series a larger lobe, and on the opposite margin three larger and flatter ones; there was also a central lobe. As in the case of the scolex just described the lobes were low and not free at their apice from the myzorhynchus.

Beneath these lobate appendages there was in the first specimen, a stout and very distinct rim on the scolex. This is represented in outline by the margin in fig. 8. Below this were four suckers. These were sessile, and there were no traces of pedicels.

At first I was inclined to approximate these specimens to the genera *Polycephalus* Braun, or *Parataenia* Linton, in which there are about sixteen longish tentacles on the scolex, and, beneath these, four suckers. But the lobate structures in the specimens which I have described here can hardly be regarded as tentacles, unless one regards the amount of contraction as excessive; while the sessile, sucker-like appendages beneath the myzorhynchal rim are not at all like the sucker of a *Taenia,* to which category the suckers in *Polycephalus* and *Parataenia* apparently belong. It is evident, from a glance at fig. 8, that the suckers are bothridia of the Echeneiform type. Only some of the costae can be seen, and the whole organ is very much contracted. It resembles the bothrium of such a cestode as *Anthobothrium* rather than that of an *Echeneibothrium,* but these organs are so versatile that one can hardly regard even this deviation from the normal form as of importance as a diagnostic character.

I am forced to conclude that these are simply specimens of *Echeneibothrium variabile* with the proboscis everted through the myzorhynchal *os.* It is difficult to con-

ceive what mechanism is involved in this process; probably the excretory canals, acting as a water vascular system may be instrumental, and the proboscis would then be turned inside out in much the same way as the proboscis of a *Tetrarhynchus* or Nemertine worm is everted. The longitudinal retractor muscles would then be put on the stretch, and being inserted in bundles, at intervals round the proboscis, they would pull on the latter so as to throw its muscular ring into lobes. This contraction would flatten the myzorhynchus and produce the prominent rim below the lobes. It would also lead to such distortion as would obliterate the usual form of the bothridial pedicels. The contraction of the bothridia themselves would doubtless be correlated with this extensive contraction of the whole scolex.

The first of these two specimens differs from Echeneibothrium with regard to the characters of the strobila. Part of this is represented in fig. 9. The neck in this specimen was distinctly bulb-shaped and without segmentation. Then follows a region in which the proglottides are of the usual form. But posterior to this they are much longer than they are broad; a condition very different from that characteristic of *E. variabile.* The prominent enlargement of the proglottides represented in the figure is no doubt accidental. But the most posterior proglottides again deviate from the typical form. They are very irregular in size and shape and almost every one presents a prominent groove on one of its surfaces, as if the margins of the proglottis had been turned over. The characters of the strobila appear to me to present a greater difficulty in the identification of the cestode as *E. variabile,* than do those of the scolex. In the meantime, pending the collection of more material, it is as well to refer them to this species.

The specimen of *E. variabile,* the head of which is

represented in fig. 4, was 110 mm. in length. At nearly all points the transverse section of a proglottis is circular. The proglottides immediately behind the neck were 0·19 mm. in width by 0·03 in length; and the terminal ones were about 0·92 mm. in width by 0·48 mm. in length.

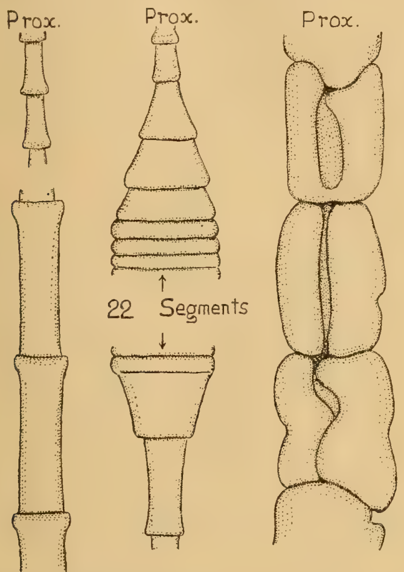


Fig. 9. ***Echeneibothrium variabile***, van Beneden. Parts of a strobila, the posterior proglottides being on the right.

Echeneibothrium dubium, van Beneden*

I have already figured † this species as a variety of *E. variabile.* Further examination of a number of specimens has, however, shown that this "variety" is, in all probability, the species referred to here. It is not always possible to observe the *os* in the myzorhynchus, and occasionally the latter structure is so greatly contracted as to present

* "Memoire sur les Vers Intestinaux." *Supplement to Tome II, Comptes Rendus, Acad. Sci.* Paris, 1858, p. 122, Pl. XV.

† *Fourteenth Ann. Rept. Lancashire Sea Fish. Laby. Trans. Liverpool Biol. Soc.*, Vol. XX, 1906, p. 310, fig. 19.

quite a different appearance from the figures given by van Beneden.

Fig. 10, page 94, represents a fully expanded specimen, such as may be obtained by killing the worm in fresh water and preserving it in weak formalin. In this specimen the bothridia were carried on rather long, versatile pedicels arranged in the form of a cross, very approximately in the transverse plane of the scolex. The bothridia are situated nearly at right-angles to the axes of

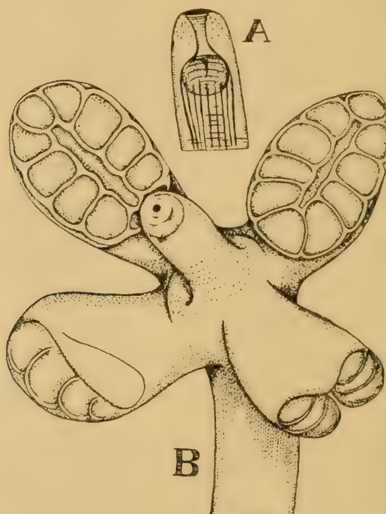


Fig. 10. ***Echeneibothrium dubium***, van Beneden ; A, the apex of the myzorhynchus ; B, the scolex. Mag. about 60 dia.

the pedicels. Each is leaf-shaped, very nearly oval in surface view, slightly pointed at the anterior extremity. They are bent so that their concave surfaces are directed outwards from the axial line of the strobila. Each bothrium has 10 loculi, these being formed very distinctly by five transverse costae on either side, and two median longitudinal costae. Two of the loculi are terminal. This arrangement is represented in van Beneden's fig. 10, but

there do not appear to be so many loculi in the bothridia figured.

The myzorhynchus is figured separately in fig. 10 A.

It is very difficult to make out the structure of this organ in whole preparations of the worm, but transverse sections shew that it is essentially the same as the corresponding structure in *E. variabile.* The terminal *os* leads into a rather long canal which terminates in the opening of a proboscidial sucker. The latter is represented by the globular structure in fig. 10 A. It is, however, not apparently muscular. The very prominent radial and concentric muscle fibres represented in fig. 5 are quite wanting, and in their place there is a rather loose connective tissue. The longitudinal retractor muscle bundles are, however, represented; they pass down in the external part of the myzorhynchus and apparently originate in the walls of the basal part of the latter.

Echeneibothrium variabile, E. dubium and *E. minimum* thus form a series characterised by the progressive reduction of a functional myzorhynchus. In the first species this organ is large and well developed, and the eversible proboscis contained in it may apparently act as an actual organ of adhesion. In *E. dubium* the myzorhynchus is still present, though greatly reduced in size; and the contained proboscis is also greatly reduced, and cannot, apparently, be everted. In *E. minimum* the myzorhynchus has entirely disappeared, and it is this difference that appears to me to justify the removal of the species from the genus in which it was originally included.

Rhinebothrium minimum (van Beneden).

Habitat: *Raia clavata and R. maculata.*

The difficulties presented by the systematic characters

of the genus *Echeneibothrium* are further illustrated by the study of the species known as *E. minimum*, van Beneden*; *E. gracile*, Zschokke†; and *Rhinebothrium* spp. Linton‡. The species *E. minimum* described by van Beneden is characterised by the presence of Echeneiform bothridia divided by transverse, but not (apparently) by longitudinal costae; by the presence of a long neck; and by the presence of a group of fairly long spines at the base of the cirrus. *E. gracile* has Echeneiform bothridia divided by both transverse and longitudinal costae; it has no neck, the segmentation of the strobila being continued right up to the scolex; and it does not possess the group of long spines at the base of the cirrus. *Rhinebothrium* resembles the genus *Echeneibothrium* in most characters, but it was founded by Linton to include cestodes possessing Echeneiform bothridia, but lacking the peculiar myzorhynchus possessed by such a species as *E. variabile*.

There is no ambiguity in the descriptions or figures of the authors quoted. P. J. van Beneden figures the bothridia of *E. minimum* most clearly and indicates no longitudinal costa, but certainly represents a long neck, and a most distinct group of long spines at the base of the cirrus. Zschokke, on the other hand, just as clearly describes and figures his worm as possessing longitudinal costae, no spines at the base of the cirrus, and no neck. No one would have difficulty in drawing up a table of specific differences.

Unfortunately the cestode described here combines

* "Vers Cestoides," p. 114, Pl. II.

† "Recherches sur la Structure anatomique et histologique des Cestodes." *Mem. l'Inst. Nat. Genevois*; T. 17, pp. 348-356, Pl. IX. Genève, 1889.

‡ "Notes on Entozoa of Marine Fishes of New England with descriptions of several new species"; *Commissioners' Report for* 1887; *United States Commission of Fish and Fisheries*, pp. 768-778, Pls. V-VI. Washington, 1891.

both series of characters and I have some difficulty in referring to it either, still more in making a new species distinct from both. But the name *E. minimum* is an old-established one, is well-known, and may be adopted, on the understanding that the form now described does not quite display the characters connoted by it.

About half-a-dozen of these worms were obtained from Ray dissected during the fishermen's classes at Piel in 1909. Evidently they are rather rare, for this is the first time that they have been found. They were about

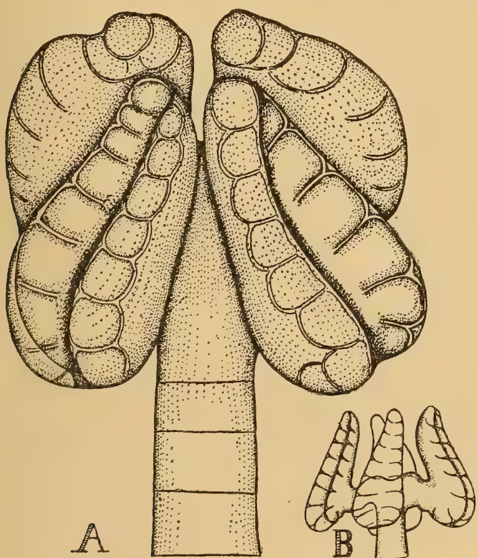


Fig. 11. *Rhinebothrium minimum* (van Beneden). Two scolices: A mag. about 70 dia.; B about 27 dia.

4 to 8 mm. in total length. There were about 12 to 15 proglottides in each of the strobilae; and the largest proglottis—the terminal one—was about 1·1 mm. in length. The scolex was about 0·8 mm. in width and about 0·7 mm. in length.

Fig. 11, page 97, represents the general appearance of the scolex in two specimens. There are four leaf-like bothridia, pointed at their anterior extremities, and broad posteriorly. Their lateral margins are rolled over, and usually anterior and posterior extremities are likewise rolled over, but in the opposite direction. This distortion of the bothrium renders it difficult to study the divisions on its external surface. But neither in stained nor in unstained preparations, nor in transverse sections can a longitudinal costa be seen. There are apparently 7 or 8 loculi on the face of the sucker along each side, one loculus being situated terminally at either end. The costa apparently cross from side to side, but it is difficult to follow their course owing to the flexure of the bothrium. Seen as in fig. 11 A, there appear to be lateral rows of distinct loculi, but this appearance is due to the optical sections of the transverse costae. Fig. 11 B, represents another scolex on a smaller scale and one of the bothridia is seen very nearly *en face* and there is no indication of a longitudinal costa. The latter figure also shows how the bothridia are situated on distinct pedicels. The latter are strongly muscular, containing both transverse and longitudinal fibres in their walls. Fig. 11 A also shows that the segmentation of the strobila is continued up to the base of the pedicels, that is, a distinct neck—far less such a long neck as is represented in van Beneden's original figure—is wanting.

The proglottides are not figured. They agree in all respects with both van Beneden's and Zschokke's figures, except for the detail of the armature of the cirrus. There is no doubt that only one kind of spines is present. The cirrus was fully extended in one proglottis and most of its surface was covered with short, slightly curved spines. No long spines were present at the base.

The absence of a longitudinal costa indicates that the

worm is *E. minimum*; but the presence of a neck, and the absence of long cirral spines indicate that it is *E. gracile.*

Neither van Beneden nor Zschokke apparently attached much importance to the absence of a myzorhynchus. Yet the presence of this most characteristic organ is part of the definition of the genus *Echeneibothrium.* I follow Linton in his suggestion, that the absence of this structure justifies the removal of a cestode possessing Echeneiform bothridia from the genus *Echeneibothrium.* Now there is no figure of *E. minimum* which shows a myzorhynchus, and the organ is absent in *E. gracile* also. I examined the specimens here described very carefully and could see no part anterior to the pedicels; and there is no evidence of a proboscidial structure in a series of sections made from one of the worms. It is true that a small, knob-like protuberance could be detected, but I think that this was only a hump on one of the pedicels. The myzorhynchus in the specimen of *E. variabile* figured on page 85, and the rosette-like structure mentioned by Olsson are very striking and prominent features of the anatomy of these animals; and even in the specimen of *E. dubium* figured on page 94, the myzorhynchus is very obvious. It seems therefore that we are justified in placing both *E. minimum* and *E. gracile* in a distinct genus, as is suggested by Linton. Whether or not these two forms are specifically distinct is a more difficult question.

REPORT ON MEASUREMENTS OF IRISH SEA PLAICE MADE DURING THE YEAR 1909.

By Jas. Johnstone.

1. INTRODUCTION.
2. THE DATA: TABLES AND GRAPHS.
3. MODAL SIZES ON THE FISHING GROUNDS.
4. AGE-GROUPS.
5. LENGTH AND WEIGHT.
6. INFLUENCE OF SIZE OF MESH.
7. SEXUAL MATURITY.

1. The data which are tabulated and discussed in the present Report relate to the measurements of some 55,000 plaice made during the year 1909. This investigation was begun in the summer of 1908 and was intended to yield results which were to be used in connection with plaice-marking experiments. It was found whenever it was attempted to make a summary of the latter results, that it would be most advantageous to consider the modal sizes of plaice inhabiting the various plaice-grounds. But it was also seen that the results of the measurements of a large number of plaice and soles would afford data of the greatest possible value in relation to the question of the regulation of the trawl-mesh—a matter, which it is needless to point out, has been the cause of much local controversy. This latter object has been kept continually in mind during the progress of the work.

It might be thought that the results of the statistics of fish landed at the ports would supply just the information required, but unfortunately this is not the case. It may be interesting to know what quantities and values of fish are landed monthly at the ports, but the really important questions which arise in the course of such discussions are not answered by the

statistical returns. We cannot tell, from the published figures, where precisely the fish were caught; what were the powers of capture employed in catching them; nor what were the sizes and condition of the fish.

I think it would be much better if the present system were supplemented by paying a certain number of masters of sailing trawlers for making accurate diaries of the results of their fishing voyages. I would refer here to a paper of Miss R. M. Lee* on the discussion of such records made by the masters of several fishing vessels working from Lowestoft. The methods employed in this Report are well worth adopting for local use; and it appears to me that if we had a record of the fishing operations and results of (say) 40 sailing trawlers working from Fleetwood, Hoylake and Douglas, a very approximate picture of the movements and relative abundance (which is what we want to know, not the quantities of fish landed) of plaice and soles in the Eastern half of the Irish Sea, and in the Welsh Bays. These vessels work over all this area, obviously they go only where fish are to be obtained, and obviously we should be utilising the accumulated experience of the masters—an experience which surely is of the greatest possible value in the consideration of fish problems. If, in addition to such records, the system of measurements of sample catches already applied were extended, we should be in possession of data of great service in the discussion of fishery regulations. Not only so, but it might be possible to trace the connection of the movements and abundance of plaice and soles (with other fish, of course) in relation to the hydrographical conditions in the Irish Sea—connections which are even now suggested,

* Report on the Lowestoft sailing trawler Records, 1903–1906. *International Investigations, Mar. Biol. Assocn., Rept. II, Pt. II*, 1904-5, pp. 89-112, (1909).

but which cannot be pushed home for want of further statistical information.

In the meantime much is to be deduced from a knowledge of the sizes and conditions of plaice caught on the various fishing grounds; and such data appear to be the only information we can, at present, obtain that is of any use in the consideration of the effects of the trawl-mesh regulations.

The measurements tabulated in this Report have been made by the officers of the Committee: Captain Wignall and his officers; and the Chief Bailiffs, Messrs. J. Wright, G. Eccles, and R. Jones; and a good deal is to be said for the trouble and care taken in preparing these records. Captain Wignall's measurements refer to plaice caught practically all over the district; Mr. Eccles' figures refer to the Mersey fishing area only; Mr. Wright's measurements were made in the Morecambe Bay area; and Mr. Jones has measured catches in Menai Straits and Carnarvon Bay. In addition to these measurements, made on board ship, a number of additional records have been made by Mr. A. Scott and myself. Numerous samples of plaice and soles taken on the various fishing grounds have been sent to the Piel and Liverpool Laboratory; and have been examined in much greater detail than was possible on board ship. This part of the work is weakest of all. The amount of time required to examine even 100 plaice thoroughly is considerable, and when we attempt to make any accurate estimates of the age and the conditions as regards maturity and nutrition, samples of more than the above number are necessary.

As a rule the measurements made by the Officers are very accurate. The lengths of the fish are recorded in centimetre groups. The use of inch scales is irritating

and troublesome when the subsequent tabulation of the measurements is made. All the figures given are mean lengths. The fish is laid on the measuring board and the division in which its tail falls is noted. All fish between n and $n+1$ cms. are recorded as n cms. The mean length is then $n+0{\cdot}5$ cms. On board the "James Fletcher" a brass pin is stuck into the measuring board opposite the tail of the fish. The number of pins in each cm. division is then read off. This method is the most accurate of all those employed. In most cases the sample of plaice sent to me for further examination has already been measured on board the "James Fletcher." On receipt it is re-measured and I give in the Table on p. 184 the results of four of such duplicate measurements. It will be seen that in two cases the numbers are practically identical. In the other two cases there is a discrepancy which is to be expected, and which is due to contraction of the fish after death. Why it is that this discrepancy is not always apparent I do not know. Possibly a fish contracts when *rigor mortis* sets in, and relaxes again when this passes off. In the two cases where this discrepancy occurs the mean difference is 0·58 cm., that is the fish when measured by Captain Wignall's men were about $\frac{1}{2}$ cm. longer than when I measured them.

All the measurements recorded in the Tables on pp. 153 to 171, were made on living fish. The first thing done, when the trawl net is cleared, is to measure and record the plaice and soles. The numbers are then entered on the log sheets. Sometimes the entire catch is sent to the Laboratory, but more usually only a part is sent. These samples are examined for length and weight, so as to get average weights and values of the coefficient k; for age, by inspection of the otoliths; for maturity, by examination of the gonads; and occasionally for food

contents. Sometimes each fish is individually weighed, but as a general rule all the fish in each cm. group are weighed and the total and average weights determined. In all cases a single fish, or a number of such, are weighed to the nearest gram. It is often difficult to state definitely the condition as regards maturity. As a rule there is no ambiguity in the case of the males: a male plaice is either mature or immature; but it is sometimes difficult to say, at some seasons of the year, whether the females are, or are not mature. Mature females are regarded as such in which the ovary extends to more than half way between the first axonost and the root of the tail.

The question of examining sample catches of plaice purchased from trawlers was considered and decided against. The localities of capture in such cases cannot, as a rule, be accurately ascertained; the fish are often selected, small ones being rejected; the conditions of the hauls from which the fish are taken cannot generally be ascertained; the fish are usually gutted; and they may be iced or uniced. No doubt the examination of fish landed at the ports may have a certain value; but it ought to be pointed out that if legislative restrictions are to be based on statistical results all possible trouble should be taken to render the latter as accurate as can be. Now the conditions under which the examination of fish landed at the ports can be carried out are not such as to make the investigation a strictly scientific one. All the measurements of length alone in this report relate to living fish; and measurements of weight in respect to length relate to ungutted and uniced fish, and are made not later than twenty-four hours after capture. Thus irritating comparisons between "entire" and "cleaned" fish, with the uncertainty attaching to the employment of

"constants" are avoided. Further, the measurements of length, and the deduction of modal sizes apply to samples —that is all the fish taken in one haul of the trawl-net.

What is a "representative sample"? It would be of service if there were some criterion or test which might be applied to a series of measurements of length, and which would enable us to say whether or not the sample catch represented truly the whole population of fish resident on the sea bottom over which the trawl was dragged. Unfortunately no such criterion exists, and one can only say that a sample catch is representative if, on trawling again and again, one gets similar results. But one cannot do this. Biologists and actuaries, who have to deal with statistical material, are able to make conclusions as to the accuracy of the data by employing frequency-curves. But it will be seen that this test is not possible in the consideration of the statistics dealt with in this Report. Nevertheless it is possible to determine roughly whether or not a sample catch with a particular net is, or is not, normal for the fishing ground and season of the year considered. An accident to the trawl—the tearing of the net, or the partial stoppage of the meshes by accumulations of sea-weed or jellyfishes—is usually indicated by the measurements. But one cannot be quite sure whether or not such unusual measurements may not after all truly represent the fish population on the sea bottom.

2. THE TABLES AND GRAPHS.

The measurements represent the mean lengths in centimetres of the fishes. The limits of error are $\pm 0{\cdot}5$. In a large catch, as for instance in some of Mr. Eccles' figures where there may be several hundreds of fish in some cm. groups, the limits of error are much smaller

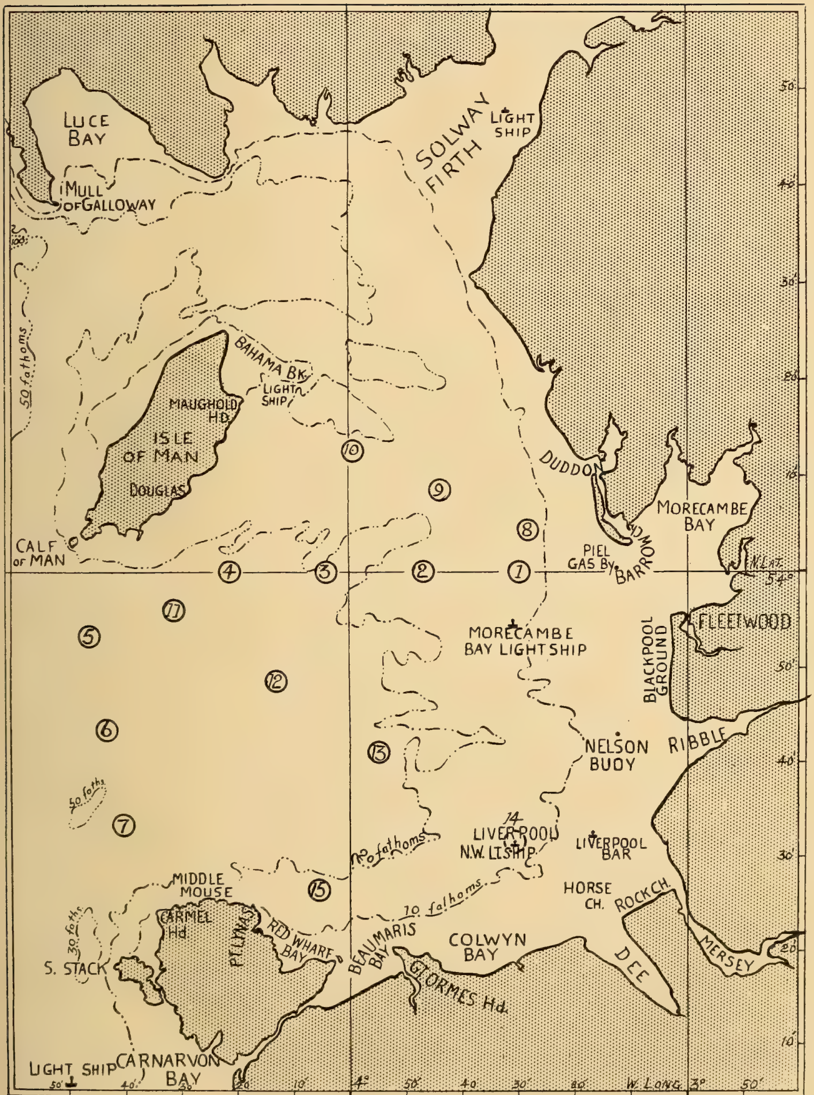
than $\pm$ 0·5. But in the smaller catches this error may actually be present. In these latter cases it is more accurate to "smooth" the figures by the use of the formula

$$\text{Mean length of group } b = \frac{a + b + c}{3}$$

this summation and division being applied to every three contiguous groups in the series.

They are grouped according to locality, beginning with the more northerly fishing grounds. The numbers of fish from Luce Bay and the Clyde are small, but are useful for comparison with the truly Irish Sea fishing grounds. The fishing grounds off Duddon Buoy, in, and off Barrow Channel, and in the estuary of the Rivers Wyre and Lune might possibly be regarded as one natural area; nevertheless they are tabulated separately: one learns to avoid "lumping" as much as possible. Blackpool Closed Ground and the grounds off Nelson Buoy are probably rather different, but the number of fish caught is small and the hauls have been combined. The Mersey area presents marked differences: Rock Channel contains quite a different kind of plaice from the grounds in Horse Channel, or near the Mersey Bar. Probably the grounds near Great Orme's Head and in Beaumaris (or Conway) Bay, and in Red Wharf Bay are very similar, but the fish taken in these areas are separately tabulated. A few catches are recorded from Carnarvon and Cardigan Bays, but so far we have not paid much attention to these parts of the District. The Sketch Chart opposite page 106 gives the approximate positions of these areas.

All the catches made in each area in each month have been added together. The month is, of course, a purely arbitrary division of time, and the ideal method would be to give the figures for each haul. But



OBSERVATION STATIONS IN 1909.

considerable space is saved by the grouping, and no serious error is involved.

All the Tables from p. 153 to p. 171 relate only to these measurements of length made immediately after capture of the fish. The actual frequencies are given under the headings "Nos.," and then these frequencies have been converted into percentages of the whole catch accurate to the first decimal place. Representation of the frequencies as percentages of the total catch assists in making comparisons, and enables us to draw graphs to the same scales of coordinates for all the catches.

The Tables "*Age-Groups, 1909,*" which occur on pages 172 to 178, represent the ages of those plaice examined according to the conventional grouping: Age-Group O includes fish 0 to 1 year old, I fish 1 to 2 years old, and so on. The first group is seldom represented in catches made with a trawl net of 6-inch mesh, and has not been considered. Age-groups higher than III are also very sparingly represented in most of the localities, with the exceptions of the offshore grounds near Bahama Bank, and in Luce Bay and the Clyde area. "Lumping" can only be practised here to a very limited degree. It is permissible to combine the measurements relating to the same month, though even this involves error during the period of most rapid growth. The measurements made during the months January to March and September to December may, however, be combined, since growth is minimal during these seasons. Obviously one cannot combine the results from different grounds without risk of error.

The Table "*Modal Lengths of Plaice captured by a 6-inch Trawl Mesh, 1909,*" p. 179, summarises the measurements so far as the modal, or characteristic lengths, are concerned. These lengths are given for each

fishing-ground and for each month represented in the statistics. The figures in brackets relate to secondary modes and indicate that the catch was obviously heterogeneous. The method of determination of the modes is given on p. 11.

Table " *Modal Lengths of Plaice of Age-Groups I and II, 1909*," given on p. 180, summarises the results of the age-determinations from inspection of the otoliths. The methods and results will be discussed later.

The Table " *Values of the Length-Weight Coefficient k, 1909*," given on p. 179, is an attempt to summarise the data relating to the conditions of nutrition of plaice in the Irish Sea. It was hoped that a more complete series of results would be attained, but in the meantime this Table may be useful for future comparisons. Average weights for the fishes examined are not tabulated in the report: evidently they can be obtained by making use of the coefficients and the length-weight formula. The coefficient k is

$$\frac{100\Sigma\, g}{\Sigma n l^3}$$

when g is the weight of all the plaice in each cm. group, n the number of fish in each cm. group, and l the mean length in cms. The results of the Table are discussed further on p. 143.

The Graphs.

Just how to graph these series of figures was a matter of some difficulty. Merely to plot the points given in the percentage columns of the Tables of length-frequencies leads to confusion for one does not easily see what are the positions of the modes, and the curves are, in some cases, very "jumpy." Smoothing the curves, as already indicated, simplifies them, but not sufficiently to assist in estimating the distribution of the lengths.

It is quite evident from inspection of the series of length-frequencies that no generalised frequency-curve can be found which would express the theoretical distribution. I have no doubt that investigation would show that some of the series might be represented by a curve belonging to one of Pearson's types of the generalised probability curve, and that by an appropriate manipulation of the constants many might be fitted. But the fit would probably be fictitious, as none of these series deals with a homogeneous group of plaice. Obviously each contains fish of Age-Groups I and II, and some include higher age-groups also. This is the case even when the frequency-curve is apparently unimodal, and in many series the curve is obviously multimodal. If a frequency-curve could be found, which could be represented by an equation—as in the case of most biometric series—the study of fish migrations would gain immensely in exactitude, for one could replace the observed distribution of length by the theoretical distribution, and then modes and other frequency-points on the curve would represent the actual distribution with less improbability than the actually observed values. But this is, apparently, not the case.

The formula suggested by Edser* helps us in some respects. It is shown by this writer that, within certain limits, the distribution of lengths in a catch of plaice can be represented by an equation of the type $\log y = A + bx$, where y is the frequency, x the length, A a constant, and b the tangent of the angle which the curve makes with the axis of x. The equation is, of course, that of a straight line. The whole catch of fish is represented by two straight lines, except near the mode. One line repre-

* "Note on the Number of Plaice at each Length, in certain samples from the Southern Part of the North Sea." *Journal Statistical Society*, Vol. LXXI, Part IV, December, 1908, p. 4.

sents the frequency of the fish at lengths less than that of the mode, and the other the frequency at lengths greater than the mode. Now if this relation were of universal application it would be of immense value, for the work of fitting a catch of fish to such a curve is simple and rapid. Further the equation shows that the gradient of the curve is a constant one; that is the number of plaice at any length, say $n+1$cms., is in a constant ratio to the number at n cms. Knowing, then, the numbers taken at any particular length—not too near the mode—we should be able to calculate what numbers were taken at most other lengths. The formula would enable us to estimate the value of the sample.

But it will be seen by plotting the logarithms of the numbers of fish taken in most of the catches tabulated in this Report, that the equation does not generally represent the distribution of lengths. One cannot expect that a close fit would usually be obtained, but it appears to me that the deviations from the curve are often too great to be due merely to errors of observation. Probably the catches consisting predominantly of fish of one age-group would fit the curve fairly well, but many catches evidently consist of fish of various age-groups, and the presence of these contrasting groups is often most distinctly indicated by the double modes in the frequency-curves. The equation $\log y = A + bx$ does not describe the distribution in such catches. If, on the other hand, a large number of plaice were caught at different times during the year, and on different fishing grounds, the variations in rate of growth due to different natural conditions, and the capture of fish at different seasons of the year would smooth down the curve and we should have a gross catch of fish, apparently homogeneous, but not really so. The equation, while useful in the analysis of commercial

statistics, does not help us greatly in dealing with true samples.

By far the best method of graphing the figures is to integrate the percentage numbers and to plot the values so obtained. This was suggested to me by Mr. H. J. Buchanan-Wollaston* and the method has been consistently applied in the analysis of the data obtained. The frequencies are summed so that any ordinate, $y_n = \Sigma_0^n y$. These values are then plotted in place of the original figures, and each value of y on the curves represents the percentage of plaice *at and above the corresponding length represented by x.* A glance at the graphs on pp. 117, 124, will at once show how greatly the analysis of the figures is facilitated; and how regularity is to be obtained from data apparently most irregular. All the curves are very smooth: the dots represent the positions of the actual figures; and the graph can be drawn by inspection without any doubt as to how it ought to go. One sees at once what is the dispersion of the group of fish, and what are the modal sizes.

The latter values are obtained by determining the points of inflexion on the curves. The graph is drawn very carefully, employing some mechanical method of obtaining a line which passes as near as possible to all the points, with as few changes of curvature as possible. As a rule this is a matter of little difficulty. The tangent is then drawn, using a glass ruler so that both sides of the curve are visible. The curvature is usually very slight at the point of inflexion, but the points where the tangent apparently begins to diverge from the curve can usually be observed fairly accurately, and the actual position of

* The method is applied by Bowley, *Elements of Statistics*, Ed. 2, p. 155, 1902.

the point of inflexion is found by bisecting the tangent between the former points. Often there are two points of inflexion, rarely three. The modes are found in this way much more easily then by methods of interpolation from the original frequency-numbers; and the accuracy is probably quite close enough when one considers the other sources of error inherent in the general investigation.

Further graphical representation of the results of the measurements by these integral curves is really the most convenient method. One does not usually want to know how many fish in a catch were between, say, 20 and 21 cms. in length, which is all that can easily be read from the differential curves; but what percentage of the whole catch is over, or under certain lengths, say 8 inches, and this is obtained at once from the graphs. The percentage of fish caught by a six-inch trawl mesh, at a certain time of the year, and on a certain fishing ground, between, say, 8 inches and 10 inches, is obtained by graphical interpolation, by drawing lines from the axis of x, parallel to the axis of y, and then, drawing lines parallel to the axis of x from the points on the curve, and letting these cut the axis of y. This is usually the sort of question that arises in practical fishery discussions.

If it is desired to trace the seasonal changes taking place during a period of two or three months, on a particular fishing ground, with respect to the size of the plaice present, the curves for these months can be drawn to the same axes of coordinates. It is useful in such cases to change the origin to the point of inflexion, finding new coordinates by the formulæ, $x' = x - a$, and $y' = y - b$, (a, b) being the coordinates of the point of inflexion. New scales are then drawn. All the conventions as to sign then have meanings: positive values of x represent

the modal length $+x$, and negative values the modal length $-x$; and positive values of y represent the modal frequency $+y$, while negative values are the modal frequency $-y$. I have drawn and discussed several such diagrams in a later section of the report, and it will be seen at once that these afford a picture of the changes taking place on the fishing grounds. Parts of each curve are, as it were, eaten away, showing how the fish population has changed as the result of the operation of several factors.

Several diagrams are given in section 5 showing the relation of length and weight in plaice. That on p. 141 represents the average weight, in relation to mean length, of plaice caught in Barrow Channel, Rock Channel and in Beaumaris Bay. Such curves can be drawn by making use of the length-weight coefficients tabulated on p. 179: they are the graphs of the function $g = \frac{kl^3}{100}$, when the suitable values of k have been substituted. The theoretical curve differs hardly at all from the smoothed curve of actual values represented in fig. 79.

The construction of the graphs representing the length-frequencies in Age-Groups I, II and III will be discussed in a later section.

The probable errors of the modal lengths have not been calculated. So far a comparison of the results of the measurements with similar data for other years is not possible. In any such comparison, due allowance will have to be made for the probable errors.

3. MODAL SIZES OF PLAICE ON THE FISHING GROUNDS.

The determination of the modal sizes of the plaice inhabiting the various fishing grounds has been the prin-

cipal object of the present investigation. A knowledge of these sizes is no less important when considering the question of the migrations of the fish than when practical regulations have to be elaborated. I would point out, in the meantime, that no attempt can yet be made to inquire into the causes of the migrations: it is obvious that investigation of this nature must await fuller knowledge of the annual hydrographic changes in the water of the Irish Sea. The data collected in the present Report do, however, possess much value when trawling regulations are being considered, and may be discussed from this latter point of view. I think the Committee now, for the first time, possess definite data with regard to the size of plaice on the various grounds within their jurisdiction. If such an investigation as the present one had been carried out at the beginning of the nineties the results of a comparison of the sizes of fish caught then and now would have been of the greatest practical value. But the trawling experiments made in the past, however valuable they may have been in the circumstances which dictated them, are too indefinite to be of much use now.

It is therefore most useful that the data of the present Report should be published in detail, so that the condition of the fishing grounds during the period 1908-1910 should be recorded for comparison for future work. Obviously the "lumping together" of the results of the hauls cannot be practised to a great extent, since one cannot foresee the purposes for which the figures may be used. But it would require a great amount of space to record the results of each haul of the trawl net separately, and I think that little, if anything, is sacrificed by combining the results for each month, in each of the areas. In many cases only one haul is recorded for the month, but when the figures are large—exceeding 1,000—they represent from two to five separate hauls.

It will be seen that the series of hauls is far from being complete with regard to each area. This is partly due to the fact that there are sometimes comparatively few plaice on the grounds in question; but it is more often due to difficulty in getting the Fishery Officers to understand their instructions. This has really been the most troublesome and discouraging part of the whole investigation, and one feels that results of value may have been lost by the failure to obtain an uniform series of data for each of the fishing grounds.

Only the actual data themselves are tabulated, and the probable errors of the modes, etc., have not so far been considered. It is quite clear that separate series of figures representing the observations of several years, or of several different areas, cannot properly be compared with each other, unless due regard is paid to the statistical errors of the values compared. But the necessity for the calculation of these factors does not yet arise, since no comparisons are made, except a few which are purely provisional in their nature. It must, however, be continually borne in mind, whenever any two curves, or series of figures, are compared with each other, that every point on the curve, or figure in the series, is only an approximation to the (unknown) real value, and is subject to more or less error. It is always possible to find the limits of this error, and when one makes a comparison, the values compared must obviously be greater than the limits of error.

We may now consider the various fishing grounds in detail. The figures relating to the Firth of Clyde, Luce Bay, and the Bahama Bank area, are records of very few hauls, and are only recorded for comparison with the Lancashire and Welsh grounds. The Clyde off-shore from Corsewall Point is a fishing ground characterised by

a much more abundant fish fauna (in the sense of variety of species) than any part of the Irish Sea. The plaice are mostly large: thus the smallest caught was 35 cms. in length, which represents approximately the largest plaice usually found on most of the Lancashire fishing grounds. Luce Bay contains plaice of nearly all sizes, and the fact that few are recorded in the Tables of less than 15 cm. in length is due merely to the condition that a $6\frac{1}{2}$-inch mesh was employed in the trawl net. When a smaller mesh is used numbers of small plaice may be taken here also. The plaice population near the banks off the North end of the Isle of Man is a migrant one, and fish are only abundant there at the beginning of the year. From Bahama Bank over to the Selker Light Ship, off the coast of Cumberland, is a spawning area, and plaice from Luce Bay, the Solway, and parts of the sea off the coasts of Lancashire and North Wales resort there to spawn. At other times there are comparatively few fish there; the bottom is as "bare as a billiard ball," the fishermen skippers say, a statement which is, to a certain extent, hyperbolical.

Duddon Banks.

The fishing grounds in this area were visited several times in the spring by Captain Wignall, when getting material for study in the fishermen's classes, and plaice were fairly abundant, the modal sizes show little significant variation during the spring months, but it is clear that the fish were steadily increasing in length. The percentage at and over 8 inches in length (20·5 cms., say) varied from 33 to 39. The curve for May can just be seen to be bi-modal, a condition which indicates change in the fish population either by immigration, emigration, or reduction by intensive fishing. In November Captain

Wignall again visited this district and made a catch. The proportion of plaice at and over 8 inches long had

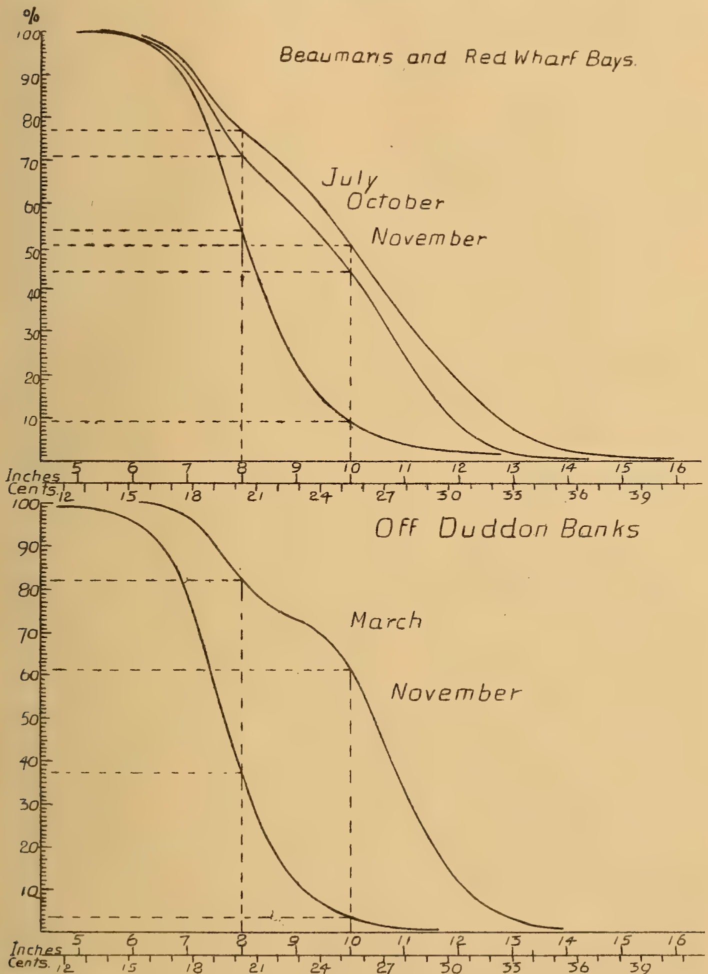


Fig. 12. Upper fig. A, lower fig. B. Curves of Percentage of plaice caught at and above each unit of length.

then risen to 82 per cent, more than in most other catches recorded in this report. From the appearance of the

curves I think that these plaice had inhabited this area during the entire summer and autumn, and had been practically unfished. The hauls for March and November are graphed as fig. 12 B.

Barrow Channel.

The sample catches made in this district were mostly small ones, being made by one of the Bailiff's sailing boats, employing a 25-feet trawl. They are, however, sufficient to indicate the changes taking place. Barrow Channel is not a "nursery," that is, it is not a shrimping area characterised by a small-plaice population, and the flukes that are found there in abundance during the summer and autumn are an immigrant population. The family of curves in fig. 13 represent the changes during the first four months of the year, and have been drawn, as already described, by changing the origin of co-ordinates in each case, so that it is situated on the point representing the modal size and frequency. Now, it will be seen at once from the graphs that the plaice population is, as it were, being eaten away from one end; it is the larger fish that are disappearing during those months, being caught by the stake nets in this neighbourhood, or perhaps migrating outwards towards the spawning area off the Cumberland coast. May is the transitional month, and an in-shore migration, or perhaps a migration from other small-fish areas, begins, so that from that month till about October plaice are abundant, and are fairly large fish. But the stock is not being replenished after the middle of the year, and we find from then that the fish become less abundant and the larger sizes are fewer and fewer as the year progresses.

The modal size shows significant variations from season to season. It is at a minimum—about 17·5 cms.—in

the months January to April, and then begins to increase towards a maximum—about 24·5 cms.—in July. This

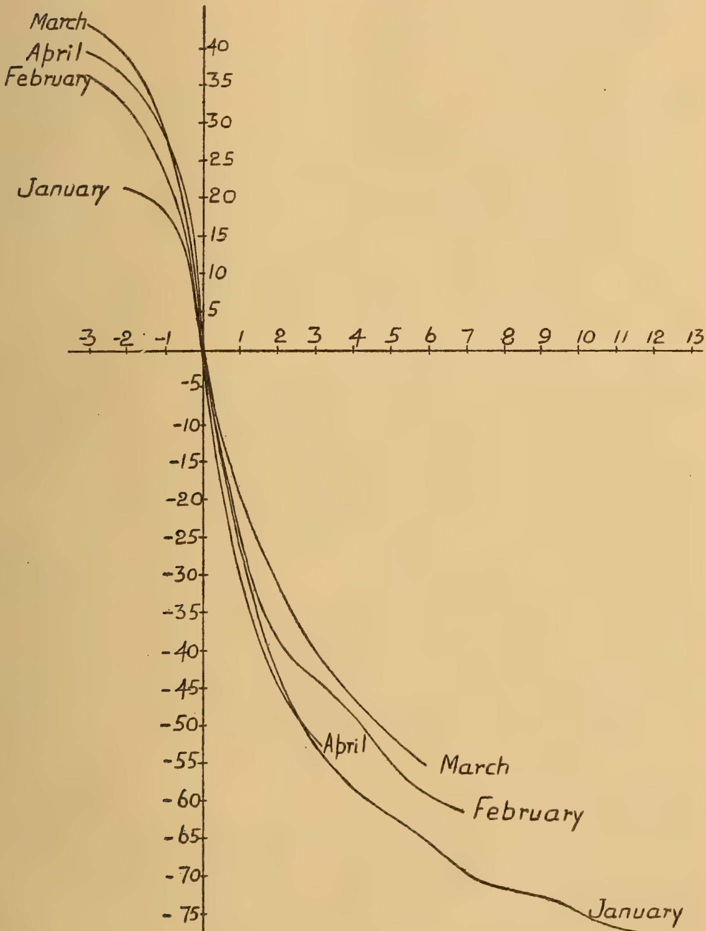


Fig. 13. Percentages of plaice at and above each centimetre of length caught in Barrow Channel during January-April, 1909. The construction is explained in the text.

increase in modal length is due simply to the growth of the fish which have migrated into the Channel, and

adjoining area, in the spring of the year. After July the modal size begins to decrease, and this is due to the fishing-out of the larger plaice.

Considering now the proportion of fish over 8 inches (a purely arbitrary size which is suggested by the fishery regulations) we see a change analogous to those indicated above takes place throughout the year. In January there were about 25 per cent. of fish in the catch at and over 8 inches in length, and this proportion steadily fell to about 10 per cent. in April. Then it rose again as steadily till July—the month of the greatest modal size—when over 90 per cent. of the plaice caught were at and over 8 inches in length. From July the proportion steadily falls towards the end of the year.

Whether or not a 6-inch mesh should be allowed for this area does not appear to me to be a question worth discussing. If the fishermen desire it they may as well be allowed to use it. When the plaice are abundant the proportion of the whole catch taken by a 6-inch mesh which is over 8 inches long is considerable; and conversely when the fish are small, so that a 6-inch mesh will catch a considerable proportion of plaice which are less than 8 inches in length, the fish are so scarce that the regulations have no practical importance.

Fleetwood Channel.

This area includes parts of the estuaries of the Rivers Lune and Wyre. The catches quoted were made by the same officer and the same gear as in the case of Barrow Channel. They do not form so complete a series as in the latter district, but they indicate a somewhat similar series of changes. The increase in modal size persists till about September, when the plaice begin to decrease in abundance. This decrease in abundance is probably

due to migration out into deep water during the autumn and early winter to a greater extent than to fishing-out. Here again the trawl-mesh may, in my opinion, be either 6 inch or 7 inch—the smaller size can hardly be of serious detriment to the general fisheries.

Only these two parts of the Morecambe Bay area have been sampled, but obviously the shallow channels higher up: near Morecambe, for instance, and towards Ulverston and Grange, on the Northern side, deserve attention. There are typical small-fish grounds on both sides—shrimping areas which constitute "nurseries," and a certain amount of trawling by second-class boats is carried on. There is also a good deal of stake-netting, and statistics of the sizes of plaice and soles caught would be desirable. It should be remembered that stake netting is a very considerable industry in this part of Lancashire and that large quantities of plaice caught in this manner are sent to the markets.*

Nelson Buoy Grounds.

There is often a considerable amount of trawling on the grounds off Nelson Buoy during the summer and autumn, and the plaice taken are mostly rather small fish. They do not appear (from the sample hauls recorded) to have been so abundant in 1909 as in some former years. The catches quoted in the tables do not show the same series of changes as in the cases of the Fleetwood and Barrow Channel grounds. We have to deal here with a plaice population migrating out from the nurseries in the estuary of the Ribble and inhabiting for some months the grounds lying between the Morecambe Bay and the Liverpool North-West Lightships and the Nelson Buoy. This plaice population becomes reduced during the

* A. Scott, 13*th Quarterly Rept., Scientific Work, Lancashire Sea-Fish. Committee,* Oct., 1909, p. 10.

autumn (1) by fishing-out, (2) by the migration into deeper waters off-shore to the South and West of the larger fish, and (3) by an along-shore migration of the smaller fish during the autumn and early winter. It will be seen that we have a bi-modal curve during March (as in the case of Barrow Channel and Fleetwood Channel in January and February), indicating extensive changes in the plaice population. Thereafter the modal sizes show little or no significant change, though perhaps there is a slight increase due to the growth of the fish. The frequencies also show little significant change; the proportion of fish at and over 8 inches in length varies from about 30 per cent. to 70 per cent., being greatest in July. The statistics are not, however, extensive enough to enable one to discuss this point further.

Fishing Grounds off the Estuaries of the Mersey and Dee.

These grounds are the most interesting of the Lancashire and Western Sea Fisheries area, since it is here that we find the "fish-nursery" in its most typical form. Fortunately we have a fairly complete series of statistics, thanks to the conscientious work of Captain Eccles, the Bailiff in charge of the sub-district. I do not mean to say that the information is all that is desirable, but the data at our disposal are very instructive. The Mersey area is really one of the most diversified in the whole Irish Sea, that is from the point of view of its fisheries. It includes large tracts of shallow water, on the margins of the channels and banks, suitable in every respect for the nurture of young fishes. These shallow waters form a very productive shrimping area. There is comparatively deep water (from the in-shore fishery point of view) in the outer channels; and there are "rough" bottoms, some of which are prawning areas and exhibit

the typical varied Laminarian zone invertebrate and fish faunas, in Rock Channel, in the Dee, and off Air Point. The in-shore parts of Liverpool Bay are probably the scene of hydrographic changes to an extent greater than any other corresponding area in the Irish Sea, and it is probable that to these changes may be attributed such remarkable instances of fish migrations on the large scale as the exceptional abundance of herrings in the early nineties, and the extensive immigration of haddocks in the same decade.

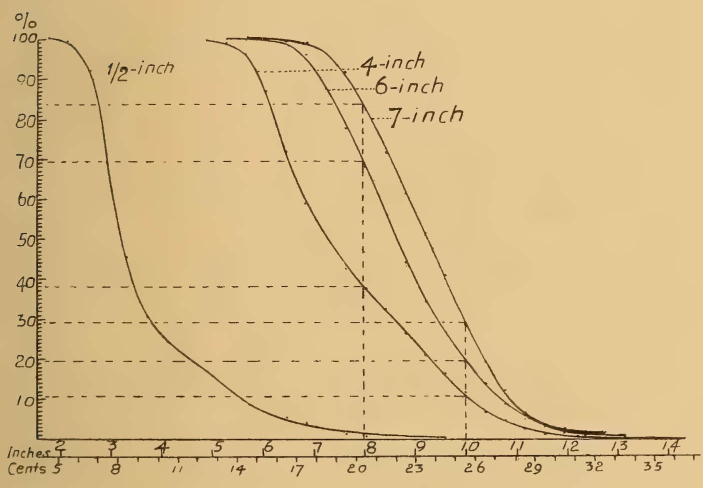


Fig. 14. Percentages of plaice at and over each unit of length, in the catches made in the Mersey area by trawl nets of various sizes of mesh.

(1) The Shrimp-trawl Catches.—These were made by a 25 feet trawl net of $\frac{1}{2}$ inch mesh. The numbers are fairly large, and the tables may be regarded as affording a very reliable picture of the size of the small plaice inhabiting the nursery grounds. It will be seen that there is little or no significant difference,

from month to month, in the modal size of the small plaice taken in the shrimp trawl: this varies from about 7 to 7½ cms., with corresponding values of frequency of about 60 per cent. to 70 per cent. That is the proportion of the whole catch which is at and over the mean modal length (=about 7·3 cms.) is about 67 per cent. At the beginning and end of the year the curves are apparently simple, but at most other times there are two modes, the

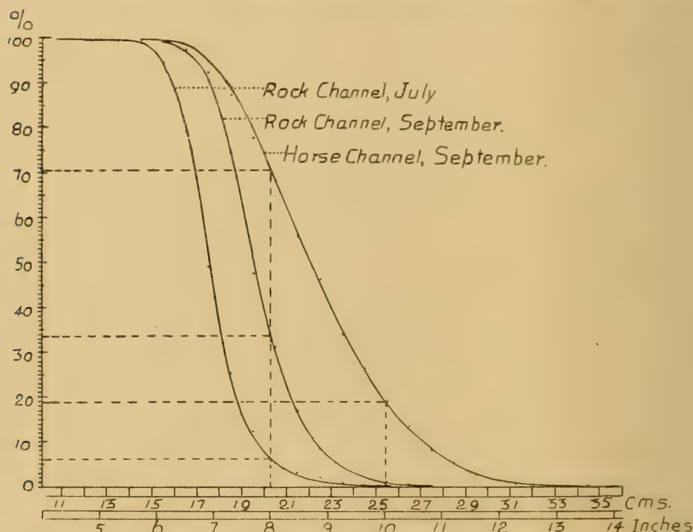


Fig. 15. Percentages of plaice at and above each unit of length, caught in the Mersey area in certain months in 1909.

lesser being due to immigration of larger fish at the beginning of the year, and to the growth of the small fish at the latter end of the year. The mean proportion of the total catch which consists of plaice between 5 and 9 cms. in length is very nearly 66 per cent. That is to say, a shrimp trawl-net of 25 feet beam and ½ inch mesh catches a certain number of young plaice,* and about

* Average values for the numbers of small plaice taken are given by Dr. Jenkins and myself in *Ann. Rept. Lancashire Sea-Fish. Laby.* for 1900, p. 39, 1901.

two-thirds of these are from 2 to $3\frac{1}{2}$ inches in length.

(2) The 6-inch trawl-mesh catches—Rock Channel.—Except for the end of the year, when the catches were rather small, plaice being scarce in Rock Channel, the figures recorded in the tables afford reliable pictures of the kind of fish inhabiting this part of the district. It will be seen that we have to deal here with a typical "small-fish" population. The modal sizes vary between $16\frac{1}{2}$ and 19 centimetres, differences which do not appear to me to be of significance. At the middle of the year (June) the modal size is least and the frequency curve shows two maxima. This bi-modal distribution is due to the growth of the plaice; about this time vast quantities of the smaller fish previously less than about 10 cms. in length have grown to be large enough to be caught in numbers in the 6-inch mesh trawl net. These little fish decrease the modal size and swamp the large plaice, producing the bi-modal curve. Before this time the predominant fish population represented in the catches were those of both of the two previous years' spawning; after June the predominant part of the catch consists of fish of the previous year's spawning.

Considering the plaice which are 8 inches long and less than 8 inches long, we find that from March to July the proportion of the whole catch consisting of fish below this length varied from 80 per cent. to 87 per cent. In June there are about 93 per cent. of plaice less than 8 inches long in the catch. After the end of June the percentage falls. In September 69 per cent. were less than 8 inches in length, in October 78 per cent., in November 50 per cent., and in December 40 per cent. But the catches during the latter two months were small ones. When these figures come to be compared with

those of future years, it will be necessary to pay due regard to the probable errors, but in the meantime we may say that of all the plaice caught by a 6-inch trawl-net in Rock Channel, about 64 per cent. were less than 8 inches long.

Six-inch trawl-mesh catches: Near Mersey Bar.—There are few of such catches recorded, but it will be seen at once by a glance at the tables that a rather different class of plaice are taken in this part of the Mersey area. The modal lengths vary from about 18 to 21 cms. Roughly speaking, we may say that the modal length is about 8 inches. Then about 46 per cent. of the plaice are less than 8 inches long, as compared with about 64 per cent. in the Rock Channel area. But the dispersion of the sizes in the Bar catches is much greater than in the catches made in the former area, and quite a fair proportion of medium-sized fish are taken.

Six-inch catches: Horse Channel.—Sample catches were made in this area during the months June to November inclusive, and the numbers of fish taken are large enough to enable us to form a reliable opinion as to the effect of this means of capture. The modal lengths vary from 18·3 to 21·5 cms., and are significantly greater than in the Rock Channel ground. The curves are in all cases bi-modal ones, and, as in the case of the catches made near the Mersey Bar the dispersion is much greater than that exhibited by the catches in the small-fish area. The proportion of plaice less than 8 inches long in the catch is about two-thirds in June, and falls to about one-quarter in September. Then, as the result of fishing-out, perhaps also of emigration into deeper water, the proportion of fish under 8 inches in length rises, and is about 40 per cent. in November.

It will be seen that there is a notable difference between the sizes of plaice taken in the 6-inch trawl net when worked in Rock Channel and the closely adjacent shallow waters, and in the deeper water in the outer channels. In the former area the 6-inch trawl mesh undoubtedly catches a fairly large proportion of small plaice of comparatively little marketable value. In the deeper water off-shore this proportion of small plaice is much less, and may be neglected. I see no reason why a 6-inch trawl-mesh should not be regarded as a reasonable instrument of capture. It may be urged that it is a destructive engine in shallow waters such as those in the Rock Channel; but I do not think we have evidence enough to justify us in preventing its use if the fishermen should strongly desire it. I will, however, return to this point later on.

The Beaumaris and Red Wharf Bay Area.

The fishing grounds West from the estuary of the Dee are characterised by a plaice population in which the fish are considerably larger than in the shallow waters off the coasts of Lancashire and Cheshire. The fishery on these grounds is an autumn or early winter one. Sometimes the bulk of the plaice are taken near Colwyn Bay, as during the winter before last; but in other years large quantities of plaice are taken in Red Wharf and Beaumaris Bays. In the later months of 1907 and the beginning of 1908 there was a very profitable plaice fishery in Red Wharf Bay. At the end of 1908 the fish were most abundant, and were largest, off Colwyn; and at the end of 1909 the biggest catches, and the largest plaice, were obtained from the fishery grounds immediately round Great Orme's Head and in Beaumaris Bay. At the very end of the year large plaice began to be

plentiful in Red Wharf Bay. These changes are, no doubt, to be associated with variations in the hydrographic conditions of the sea in these regions, but just what is the nature of these associations is as yet doubtful.

Fairly large catches of plaice were made in the Beaumaris and Red Wharf Bay area by Captain Wignall during the autumn of 1909, and the figures appear to me to be very reliable and to give us a very accurate picture of the distribution of sizes on this fishing ground. I have grouped together all the catches made in "Beaumaris Bay," "Conway Bay," "Off Orme's Head," and in "Colwyn Bay." All these grounds may be regarded, during this last fishing season at least, as constituting practically the same area. The catches made in Red Wharf Bay have, however, been kept separate from the rest, though it would not have made much difference to the results had they been incorporated with the rest.

It will be seen from the tables and from the curves in fig. 12 that the plaice taken were smallest in June and July, and that they become larger as the end of the year approaches. The curves are uni-modal in June and July, the mode being about 20 cms. After August the dispersion increases and the fish become, on the whole, larger. From September to the end of the year the curves are bi-modal. Those for November are remarkably similar, and the October and November curves can be superposed, so alike are they in magnitude and phase. This similarity appears to me to indicate that we are dealing here with samples which are of great reliability. In December the modal sizes are greater than in the preceding months. The double mode indicates the presence of plaice of Age-Groups II and III, though, of course, the positions of the modes are not exactly those of the maximal sizes in those groups. Plaice up to six years

of age were represented in these catches, though not abundantly, and the older fish were not numerous enough to affect the form of the curves.

The difference between these plaice and those taken off the coasts of Lancashire and Cheshire is best seen when we compare the proportion of the whole catch consisting of fish less than 8 inches long. In June and July about 46 per cent. of the catches made in Beaumaris Bay were plaice less than 8 inches long. The corresponding percentage for Red Wharf Bay in July was 44. But on both grounds from August onwards the proportion of fish less than 8 inches long drops to about 25, and in some cases was less than 20.

Obviously the question of the restriction of the mesh has little interest in relation to these grounds. The proportion of small plaice taken by the 6-inch trawl-mesh in those months when the fish are abundant is so small that we cannot conclude that the general use of this net can do any harm to the fishery, and if the fishermen wish to employ it in these in-shore waters I see no reason why they should not be allowed to do so.

Catches made in Cardigan Bay.

Comparatively few sample catches have been made in Carnarvon and Cardigan Bays, and I quote only those taken from the trawling grounds off New Quay Head, in Cardigan Bay. We have to deal here with fairly large plaice; thus the modal sizes vary from 29 cms. in February to 21 in May. Obviously a migration of smaller fish was taking place about the end of this period; thus the modal size is decreasing all the time, and it is evident, from a consideration of the curves for March, April and May that this is due to the swamping effect on the large fish population, of a host of immigrant

smaller plaice, and not to fishing-out. In February only 2 per cent. of the fish were under 8 inches in length, in March 6 per cent., in April 17 per cent., and in May as much as 21 per cent. Apparently the conditions at the south end of Cardigan Bay are very different from those off the coast of Lancashire. The natural conditions are no doubt not the same, but much of the difference may be due simply to the fact that the fishery at this part of the coast is very much less intense than in the highly exploited grounds to the North. The distribution of plaice in Cardigan and Carnarvon Bays would be well worth closer attention than we have been able to give to it.

4. AGE-GROUPS.

The determination of the modal lengths of the plaice inhabiting the various fishing grounds in the Lancashire district has been the most unsatisfactory part of the whole investigation. The total number of fish examined is a little over 2,500, probably much too small a number. If these fish had all been collected from one fishing ground, and during the same time of year, reliable figures for the lengths of plaice one, two and three years of age might have been obtained. In the Report on this work, published in 1909,* I gave particulars relating to the examination of about 1,000 plaice caught during the year in the northern part of the district; and it was seen, on considering these figures that the process of "lumping" the fish caught, even on grounds which are not far distant from each other, led to erroneous conclusions. Far more faulty, however, was the method of combining the results of examinations of fish caught at different times in the year; for while the curve of growth of the fish is a

* *Lancashire Sea Fisheries Report for* 1908, p. 33, 1909.

continuous one, that representing the age is discontinuous. It is sometimes difficult, at particular seasons in the year, to be sure of the number of rings of growth in the otolith. A faint marking on the margin may be the beginning of another opaque ring, but the appearance may also be only the effect of refraction. A week or so later it might have been possible to ascertain with certainty the age of the otolith in question; but there would be a difference of a whole year in the recorded age of the fish, while the length of the latter would hardly have changed. Obviously the "lumping" together of catches consisting of plaice which were passing through this transition stage, and others taken before or after the cessation of growth, would produce discordant results.

The plaice examined in 1909 are therefore grouped according to the precise fishing ground and the month of capture. The disadvantage inherent in this classification of the results is that small numbers of fish must, of necessity, be considered. It would, of course, be possible to examine, say, 1,000 plaice from each fishing ground during three or four sample months of the year, but the practical difficulties of investigation on such a scale are very obvious. On the whole it is better to deal with small numbers of fish taken under precisely similar conditions, and trust that the summation of the results of several years' investigation may afford accurate data for age-determinations.

The tables on pp. 172-178 include the results of all the measurements made in 1909, and are summarised in the table on p. 180. It will be seen, by inspection of the latter, that there are gaps in the series representing each fishing-ground; and these gaps are due partly to the fact that plaice are not present on each ground in abundance throughout the year, and partly to the not

unnatural reluctance of the Fishery Officers to misapprehend their instructions that large samples of the fish caught by them should be sent to the laboratories periodically. The modal lengths tabulated on p. 138 have been determined by integration of the original frequency series, as in the case of the other tables. As a rule there is little difficulty in estimating very approximately the position of the modal frequency. When the curves are drawn it is often apparent that one or other of the extremities is unrepresented in the series, but this may affect very little the value of the mode. As a rule, when 30 to 50 fish of any of the Age-Groups are examined, the mode can be ascertained. It is sometimes impossible to determine the modal length of Groups I and II in the same catch, the latter consisting predominantly of fish of the same year; and as a rule it is impossible to ascertain the length of plaice of Age-Group III except in one or two of the Lancashire fishing grounds. Plaice of more than three years of age are not allowed to inhabit the shallow waters off the coasts of Lancashire and North Wales in very great numbers.

It would be a result of very great value if one could determine the law of variation in growth, so that a theoretical frequency-curve could be substituted for the observed distribution. Unfortunately this has not been possible. In order to determine the equation of the curve which the observations would fit with least improbability, a very large number of plaice would have to be examined, and one would have to collect the fish under conditions which would ensure the homogenity of the material; that is, they must be caught at the same time of year, and on the same place, so as to avoid the influence produced by migrations; and the catches would have to be made by means of trawl nets of different meshes. For just as no

single plankton net can be expected to collect a representative sample, so no one trawl-mesh gives us a representative catch of the fish resident on the sea-bottom.

Three groups of plaice caught during 1909 have been examined statistically in order to see whether the distribution of the length followed the normal law. The results of these examinations are given in Tables on pp. 181-182, and the curves (figs. 16 and 18) express the distribution graphically. It will be seen that the correspondence is in no case a close one, and that it is probable that the distribution would be better represented by a skew curve.

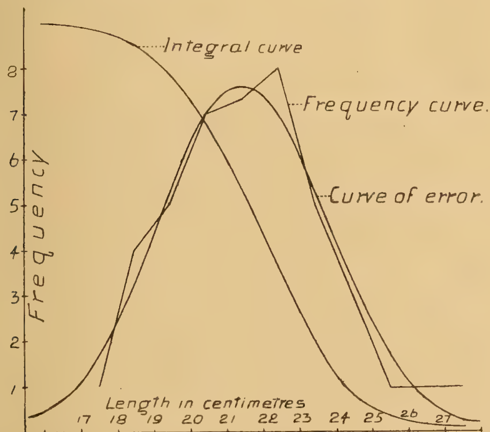


Fig. 16. Catch of 44 plaice from Barrow Channel, 12 July, 1909, Gp. II ♂. Correspondence with curve of error.

I thought it might be possible to decide whether or not the deviations from the modal length in a number of young plaice, of very approximately the same age, were distributed according to the normal law of error. For this purpose a number of measurements made by Mr. H. C. Chadwick were available.* The fish had been

* Referred to in *Annual Report of Liverpool Marine Biology Committee* for 1907, p. 13.

spawned in the large pond at the Port Erin Hatchery about the 26th of April, 1906; probably the error in this

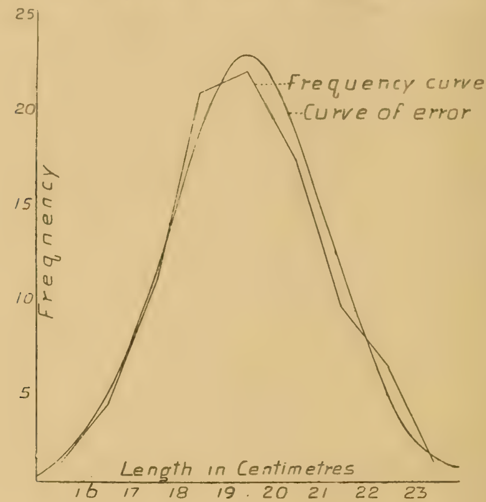


Fig. 17. Catch of 95 plaice from near Nelson Buoy, June, 1909. Gp. II ♂. Correspondence with curve of error.

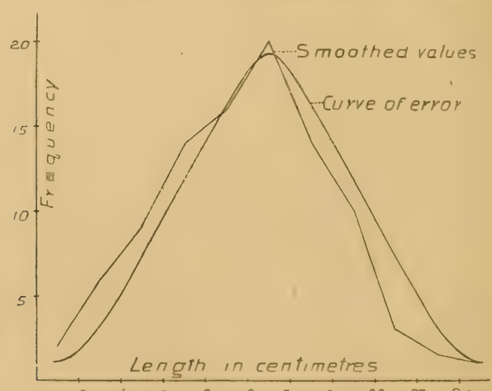


Fig. 18. Catch of 99 plaice from near Nelson Buoy, June, 1909. Gp. II ♀. Correspondence with curve of error.

date does not exceed ± 14 days. The eggs collected from the pond were, as a rule, put in the incubating boxes, but

a large number had been put into a division of the pond, where they developed until the close of the spawning season of the following year. During the winter of 1906 the whole pond had been emptied, cleaned out, and the bottom was allowed to dry. It is, therefore, impossible that any small plaice were there at the beginning of the hatching season of 1906, and we may be confident that the fish measured in May, 1907, were just over one year old.

The sizes of the 200 plaice examined are tabulated on p. 183. They were measured to the nearest $\frac{1}{8}$ inch, and the figures are grouped into $\frac{1}{4}$ inch classes. The mode is at 2·625 inches, a result which agrees well with what we know of the life-history of the plaice in the sea, and the limits of variation are also concordant with such impressions as I have received on looking over the contents of the catches made by shrimp trawls worked on shrimping areas when small plaice are abundant. It will be seen from the table on p. 163, representing the results of shrimp-net hauls in the Mersey, that the highest percentage of small plaice caught is that about 6·5 centimetres (approximately 2·6 inches). I do not know what these small plaice fed upon in the spawning pond, but the latter was said to contain a very abundant copepod fauna, and on the Mersey grounds copepods form the diet of small plaice up to about 1 inch in length.

It is evident from a glance at the series of measurements on p. 183 that the sizes of these 200 young plaice cannot be arranged in a simple frequency curve. At about 4 inches the numbers of fish in each class begin to increase. It is true that this increase is small, and the total instances are not enough to enable one to be sure as to its meaning. It is, however, quite possible that we are really dealing with heterogeneous data. The spawning pond was stocked with plaice collected (1) from Port Erin

Bay, and (2) from Luce Bay. Now the latter area is strictly preserved against trawling, while the sea round the Isle of Man is certainly fished for all it is worth. Further, there is a very abundant plaice population in Luce Bay, while that round the South end of the Isle of Man is very sparse. It is, therefore, quite possible that the local plaice were different from those of Luce Bay, and had a more rapid rate of growth than the fish of the latter region. This difference in the spawning fish would result in a difference of rate of growth in the larvae and young fish. The double mode, in fact, may be taken to indicate two strains of fish.

On the other hand, it may simply indicate that the rate of growth of the plaice is such that the deviations from the modal character for a homogeneous group form a skew curve. It is not possible to settle this point in the meantime. I have, however, attempted to make a correspondence between the deviations exhibited by the Port Erin plaice and the normal curve of frequency error. Taking the mode at 2·625 inches, the part of the series as far above the mode, as the smallest fish is below it, is neglected. The standard deviation and modulus have, however, been calculated for the entire series; but in constructing the algebraic curve the modulus has been taken as 0·8 instead of the calculated value, 0·712. Points on the normal curve are then found by a method suggested by Mr. A. L. Bowley.* The correspondence is not good, and though it is not quite justifiable to conclude that the observed measurements are those that would result, with least improbability, from the normal curve, it seems to me that the distribution is almost as likely to follow the latter law, as that expressed by the equation of one of the asymmetrical frequency curves. The

* This differs slightly from that indicated in Mr. Bowley's *Elements of Statistics.*

symmetrical curve would not, strictly speaking, be the normal curve of error, deduced from the binomial expansion, with branches extending to infinity in either direction, but rather Pearson's "Type II," that is,

$$y=y_0\left(1-\frac{x^2}{a^2}\right)^m,$$

which is symmetrical, but limited in both directions.

Leaving for further investigation the question of the application of a theoretical frequency-curve, we may consider the modal sizes of plaice of Age-Groups I, II, and III, inhabiting the coasts of Lancashire and North Wales. It is quite impracticable to attempt to estimate the ages of fish older than these, for such plaice are so sparingly represented on the in-shore fishing grounds as to make any such estimate subject to considerable error. During the autumn there is indeed an immigration of large mature plaice into shallow water, so that fish belonging to Age-Groups IV and V may be taken in Barrow Channel and off the coasts of the North Welsh counties, but the number of such plaice examined is far too small to be capable of statistical treatment. It will also be seen from the tables that fairly large plaice may be taken on the banks off the North of the Isle of Man, in the Firth of Clyde and in Luce Bay, and the results of several hauls on these grounds are given for the purpose of comparison with the Lancashire fishing area.

The plaice caught on the latter grounds belong almost entirely to Age-Groups 0, I and II. Barrow Channel, the shallow water in the estuaries of the Rivers Lune and Wyre, the grounds off Nelson Buoy, and the Rock Channel in the Mersey area may be taken to represent the Lancashire in-shore area, and there is comparatively little difference in the modal sizes of the plaice captured on these grounds. The table on p. 180 may be very briefly summarised as follows:—

Group I. Modal lengths in the spring months (January-March).

(1) Barrow Channel:
Males, 18 cms. long; females, 18 cms. long.

(2) Lune and Wyre:
Males, 17 cms. long; females, 17 cms. long.

(3) Rock Channel:
Males, 17·5 cms. long; females, 18 cms. long.

,, Modal lengths in the autumn months (September to November).

(1) Barrow Channel:
Males, 19 cms. long; females, 19 cms. long.

(2) Lune and Wyre:
Males, 18 cms. long; females, 18·5 cms. long.

(3) Rock Channel:
Males, 19 cms. long; females, 19 cms. long.

Group II. Modal lengths in the spring months.

(1) Barrow Channel:
Males, 23 cms. long; females, 23 cms. long.

(2) Lune and Wyre:
Males, 18·5 cms. long; females, 21 cms. long.

(3) Rock Channel:—
Males, 21 cms. long; females, 21·5 cms. long.

,, Modal lengths in the autumn months.

(1) Barrow Channel:
Males, 22 cms. long; females, 22 cms. long.

(2) Lune and Wyre:
Males, 24 cms. long; females, 22 cms. long.

(3) Rock Channel:
Males, 21 cms. long; females, 21·5 cms. long.

The differences in the modal lengths of plaice taken from these various grounds are very slight, and may be expected to be less than the probable errors of the deter-

minations. It is to be noted that there are no marked differences between the lengths of the males and females of each Group: what differences there are are often reversed. It is also to be noted that the differences between the modal lengths of Age-Groups I and II are very slight, amounting to only 3 to 4 cms. I expected that the average growth during the third year of life would have been greater than is indicated by the above figures.

Quite a different plaice population is contained on the grounds off Rhyl, round Great Orme's Head, and in Red Wharf Bay. Here the fish belonging to Age-Group I are far less in proportion to the older fish than on the Lancashire fishing grounds. So few fish of this group were contained in the sample sent to me that I have not attempted to estimate their modal lengths; the figures are, however, given in detail in the tables. On the other hand, Age-Group III is represented in sufficient numbers to enable the modal lengths to be determined.

Age-Group II. Beaumaris Bay and adjacent grounds.

July: Males, 19·5 cms. long; females 20 cms. long.
Nov.-Dec.: Males, 23 cms. long; females, 23 cms. long.

Age-Group III. Beaumaris Bay and adjacent grounds.

Nov.-Dec.: Males 27 cms. long; females, 29 cms. long.

5. LENGTH AND WEIGHT.

The object of determining the weight of the plaice taken on the various fishing grounds was to find a numerical expression for the "condition" of the fish, both with regard to season and fishing ground. One knows very well when a plaice is "in condition" from

its general appearance, but it is obviously desirable to have some measures of this quality, in order that it may be accurately compared in different samples. The samples received represent most of the fishing districts, but fairly good series were obtained only from the Barrow Channel and the Mersey shallow water grounds.

As a rule the method of weighing was to sort out the fish in each sample into centimetre groups, and then to take the total weight of all the fish in each group. Sometimes each fish was weighed separately. The weight was always found to the nearest gramme, whether in a single fish or a number. Mature females with ripening ovaries were weighed, but the results were not made use of in determining averages. The tables apply, therefore, to immature females or to mature and immature males.

The average weights themselves are not published: obviously to do so would involve much space, and the table of values of the coefficient k can be used to find the average weight of the plaice of each fishing ground and season represented. The weight $= \frac{l^3}{100} k$, l and the weight being taken in centimetres and grammes respectively. Since the k of the table is itself an average number, the weight will represent the mean for the place and time in consideration.

Fig. 19 represents the increase of weight with length in the case of four typical catches of plaice. That from Barrow Channel in July may be regarded as representing plaice in good condition; while the catch for February represents the fish when in the worst condition of the year. One sees that the differences are fairly considerable: a 10-inch plaice in good condition weighs about $6\frac{2}{3}$ ounces, while a fish of the same length taken at the time of its worst condition weighs only $5\frac{1}{3}$ ounces. These July fish were in first-rate condition and were

mostly feeding on small mussels, about $\frac{1}{4}$ to $\frac{1}{2}$ inch long. The catch from Beaumaris Bay in September consisted of

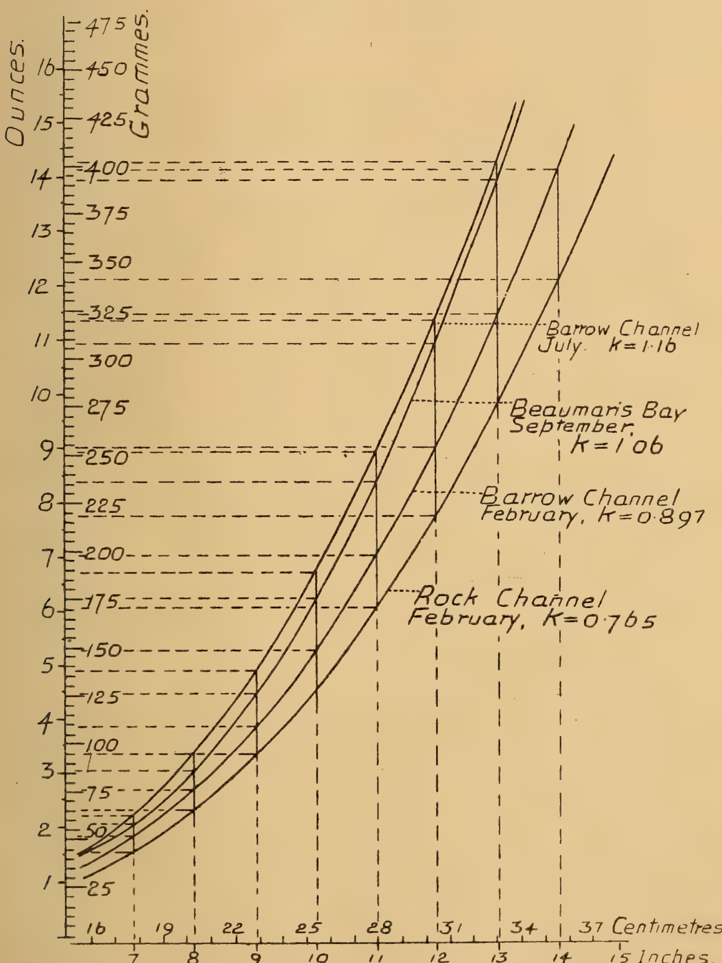


FIG. 19.—Average weights of plaice at each unit of length from various fishing grounds.

fish nearly as good, but of all the plaice sampled, those from Barrow Channel in July were the best. The February

catch from Rock Channel represents the poorest plaice taken in the Lancashire and Welsh district, with the exception of one catch from Menai Straits in March—a 10-inch fish from the Rock Channel catch weighed only about $4\frac{1}{2}$ ounces.

The figure is not the graph of the function $\frac{k\,l^3}{100}$ but each of the curves is a smooth line drawn as near as possible to the points representing the actual average weights. It is not drawn absolutely correctly and is intended to show the relative weights at different places; closer approximations can be made to the weights by calculating from the table of values of the coefficient k. Really true values are not really obtained either by this process or from a graph on which weights calculated from the formula are plotted, because the "constant" k is not absolutely a constant, but often varies slightly in the same series. If it is calculated for each centimetre group in the same catch it is frequently found that it is greater in relation to the larger fish than the smaller ones. That is, the plaice does not grow equally in all dimensions, and the ratio of length to thickness or average width probably varies with increasing age.

The values of the coefficient k for three of the series are plotted in fig. 20. It will be seen that they form curves with one maximum, which in the case of the two Channels is in July. The curves probably rise to the maximum more steeply than they fall to the minimum, but the number of observations is not great enough to enable us to be quite sure of this. The minimum appears to be in January. About the end of November plaice cease to feed as a rule, and very little is found in their stomachs until the end of January. In the case of the plaice taken in Beaumaris and Red Wharf Bays there appears to be a notable difference in that the condition of the fish is

maintained till a later period of the year than in the other two fishing grounds.

I would direct particular attention to the differences between the condition of the plaice from these three areas. I think one can hardly regard these differences as indicative of different "varieties" or "races" of plaice in the way one would so interpret structural differences. The grade of condition appears to depend on the amount and nature of the food at the disposal of the fish on their feeding grounds, and on the density of population on these areas. But it is rather difficult to believe that the condition depends entirely on the amount of available

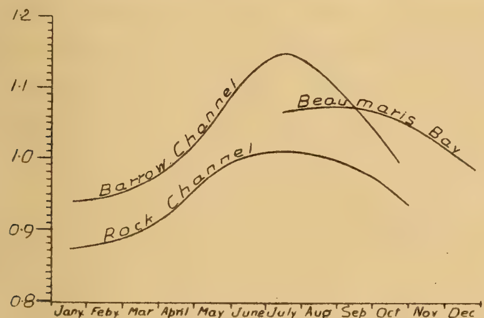


FIG. 20. Monthly variations in the value of the coefficient *k*.

food. I examined the alimentary canals of a number of plaice caught both in Barrow Channel and in Rock Channel during the last two years. As a rule the plaice in the former area contained small mussels from one-quarter to half-an-inch in length; while plaice from the latter area usually contained small cockles, *Tellina*, *Scrobicularia*, *Donax*, and *Pectinaria*, the latter animal being very abundant at times. Food molluscs seemed to be abundant in both areas. Nevertheless, one is forced to conclude that the fish in Rock Channel are not so well nourished as those in the northern area; it may be

because food is less abundant, or that small mussels form a more nutritive diet than the other animals mentioned. The latter conclusion appears reasonable, since the shells of such small, rapidly growing mussels as were found in the Barrow Channel plaice were, as a rule, exceedingly thin. However this may be, there can be no doubt that we have to deal, in the Rock Channel area, with small plaice which are below the normal in condition.

The graphs of the variation in value of the coefficient k, which we may regard as a good index of the condition of a plaice with regard to nutrition, appear to back up this conclusion. All through the year the coefficient is less, in the case of the Rock Channel plaice, than in plaice either from Barrow Channel or from Beaumaris and Red Wharf Bays; and in July the maximum is attained in the two former areas, but it is much greater in the northern than in the southern area. The conclusion that the Rock Channel plaice are below the normal with regard to condition appears to be so important that it is desirable to examine critically the data on which it is based. The values of the coefficient k represent variations in the condition of the fish; when the average weight (the "condition") of plaice of a certain length is relatively high, k is also relatively high, and *vice versâ*. Each value of k in the table on page 179 is deduced from weighings of a sample of fish varying from 40 to 150 in number. Altogether about 1,100 plaice from Rock Channel and about 740 from Barrow Channel were weighed. When there are several determinations of k for one month, the average is taken. The values of k found in the table have been smoothed, and the graphs in fig. 20 represent the monthly variation of these smoothed numbers. The arithmetic average of the value of k, for Barrow Channel plaice, for the ten months,

January to October, 1909, is 1·034. The similar average for Rock Channel plaice for the same months is 0·966. The former fish are therefore in better condition, since the average value of k is greatest.

Now these mean values are deduced from samples; obviously the latter must be unreliable to some extent, since we can never sample an assemblage of organisms in the sea without error; and it is necessary to ascertain the limits of error whenever a comparison of two or more series of samples is made. The precision of the mean depends on the extent to which the data averaged "scatter" from the maximum point in the series, and is deduced from the standard deviation. The arithmetic mean (or average) in the case of the Barrow Channel series is 1·034, and the standard deviation σ, $\sqrt{\frac{\Sigma\nu_2}{N}}=0{\cdot}0808$: $\Sigma\nu_2$ being the sum of the "second moments" about the mean, and $N=10$, the number of observations. The probable error of the mean is $\frac{\sigma}{\sqrt{N}}$ and is 0·025.

"Unless a result exceeds the expected by two or three times the probable error, it is not safe to assume that the particular case differs from the expected result." Now the mean value of k in the Rock Channel statistics is 0·966, and differs from the mean of the Barrow Channel statistics by 0·068. The difference is therefore 2·6 times the value of the probable error, and we are justified in regarding it as significant, and indicative of a real difference in the condition of the two fish populations sampled.

If a complete series of weight statistics for the plaice of the Beaumaris—Red Wharf grounds were available, we should probably find a corresponding significant differ-

ence. But there are no figures for months prior to July. The part of the curve drawn does, however, indicate that the plaice population differs from that of the other two areas. We know that the fishery in this part of the district is an autumn and winter one, the fish immigrating into the in-shore waters off the North Welsh coast late in the year. The fish do not appear ever to have been in as good condition as those in Barrow Channel during July, but they retain a high average weight until late on in the year, when the condition of both Barrow Channel and Rock Channel has fallen below the mean.

6. INFLUENCE OF SIZE OF MESH.

We should be able to find out what range of sizes of fish would be caught in trawl-nets of different sizes of mesh, by making a sufficient number of trial hauls; and this kind of information is so important, practically, that it is rather surprising that it has not been obtained long before the present time. A number of such comparative hauls were made in the earlier years of the Committee's work, but I think the results are far too indefinite and inexact to be of much use. It is quite absurd to describe a catch of fish as consisting of so many over, say, 8 inches in length and so many under 8 inches, for one cannot say how far below or above the standard size the fish were. It is only by measuring each fish taken, and then exercising some care in the calculation of probable average or modal sizes, that results capable of standing criticism can be obtained. I do not think that very good results can be obtained from the use of a double net, a net of 4-inch mesh, say, outside one of, say, 7-inch mesh. Obviously the wide meshed net would not make the same catch as if it were used alone, for the draught of water through it would be diminished by the small-meshed net

outside. We can ascertain the range of sizes of fish caught in nets of particular mesh only by using each by itself.

Very few hauls by nets of mesh other than 6 inches have been made; they are all recorded in the tables on pp. 163-165. Captain Eccles used nets of $\frac{1}{2}$-inch mesh (p. 163), 4-inch mesh (p. 164), 6-inch mesh and 7-inch mesh (p. 165). The results are rather few yet for statistical treatment, and one must remember that the range of sizes of plaice taken in the nets will be affected by various factors. Thus an unusually large proportion of invertebrates, say large jelly-fishes or star-fishes, in the catch will be associated with a larger proportion of smaller fish; while a difference in the speed at which the net is dragged must also affect the catch. I do not suppose that a 4-inch net dragged from a steamer would give the same range of sizes as the same net dragged over the same ground by a sailing boat. Probably two fishermen working the same boat and net over the same ground would not get similar catches. In order to obtain reliable measures for the catching powers, with regard to the size of fish, of trawl nets of different meshes it would be necessary to make a large number of trials on the same ground and by the same boat and fishermen. I should think that a dozen hauls by nets of 6 and 7 inch mesh during the same month, on a ground where fish were abundant during the whole period, and arranged so that so many comparison hauls were made on alternate days, would give fairly reliable results. Of course it might be objected that the fish population had changed during the interval, and that it would be difficult to trawl over precisely the same ground each time, but these objections appear to me to be cavilling rather than real criticism. At any rate, no other practicable means of investigation can be suggested.

Fig. 14 represents the catches made by four different trawl nets—a shrimp net of ½-inch mesh, and three fish trawls. They were all made by Captain Eccles from a second-class fishing boat in the Horse Channel area during September; the actual counts of the fish taken are given on pp. 159-165. The shrimp net was used once and caught 579 plaice; the other nets were used several times each and caught over 1,000 plaice each. When the figure was first drawn one of the 6-inch net hauls was omitted, but on replotting the total catch it was seen that the curve was not materially altered. I do not propose to deduce any "factor" for the catching power of each net, but quote the results as those obtained by a thoroughly experienced fisherman in certain particular cases. The shrimp net, it will be seen, caught comparatively few fish over 5 inches long. Considering plaice of 8 inches in length, the figure shows that about 38 per cent. of the catch of the 4-inch net were of this length and over it; 70 per cent. of the catch of the 6-inch net were 8 inches and over; and 84 per cent. of the catch of the 7-inch net were at and over 8 inches.

The 6-inch Trawl-Mesh and Regulations

It has been maintained that the universal employment of a trawl-net of 6-inch mesh in shallow waters is likely to be detrimental to the fisheries in general. I do not think that this is likely to be the case with regard to plaice—at least the figures compiled in this Report do not seem to me to support the above contention. Obviously a narrow-meshed net is likely to be destructive only in the shallow waters, and at those times in the year when small plaice are so numerous as to form a large proportion of all the fish on the ground. On grounds such as those off Colwyn, off Great Orme's Head, and in Red Wharf Bay a 6-inch trawl-net is not, in my opinion, a wastefully destructive instrument of capture. Even

in the in-shorė waters of Barrow Channel, I do not regard the destruction of small plaice by the 6-inch net as wasteful. It is only in such an area as that in Rock Channel that the 6-inch trawl appears to have taken an undesirable proportion of plaice of lengths less than 8 inches.

But there is evidence that this particular area is an over-crowded fishing ground. There are enormous numbers of plaice of 5, 6 and 7 inches in length. Even in September, when the fish were, on the whole, largest, there were only 30 per cent. over 8 inches long in the sample catch. Now, plaice of 8 inches or thereabout do not migrate out from shallow water. It is, probably, only after they have grown to over this length that they move out into the deeper channels, in large numbers at least. While they remain in the shallow waters there are so many of them that the available stock of food does not appear to be sufficient; the condition is below that of plaice from most other fishing grounds; and they are gradually destroyed by other animals. Thus the figures in the tables show that average weight of plaice in Rock Channel is significantly less than that on the other grounds. I do not lay much stress on the figures for the lengths of these plaice in each of the first two complete years of their life, but so far as these figures go they seem to show that plaice of Age-Group II (over two and less than three years old), are smaller in Rock Channel than they are on other grounds. In the samples of plaice taken from this ground one does not notice a great increase in length as the year progresses. The fish remain small all the time, for they do not grow quickly, and their numbers are continually being added to from the nursery area. There are too many of them, and they might as well be captured by the fishermen as destroyed by their natural enemies. In a certain sense we cannot

have too many plaice, if we could put them where they would be of use to the industry. It is just the same as the case of the small mussels; if we can transplant a fair proportion of the latter into grounds where they will grow to be big enough to be marketable, then restriction of the legal size would be of service to the industry; but if we do not transplant them, then (apart from economic reasons) there is no reason why the fishermen should not be allowed to take them. If we could transplant the undersized plaice from such areas as Rock Channel to other fishing grounds where they would grow well, protection and restriction of the trawl-mesh might be of advantage. But as it is, these restrictive regulations appear to me to be of doubtful utility. Before one advocates restriction of mesh on these grounds he ought to be sure that this kind of regulation would result in an increase of larger plaice elsewhere. Can we be sure that this result would be produced?

Even if it were produced; even if restriction of the powers of capture within territorial limits were to lead to an increase of larger plaice outside territorial limits, would one be justified in advocating such restrictive legislation? For it would involve penalising the in-shore fishermen possessing only small fishing vessels, or fishing by stake-nets, trammels, or "tees," for the benefit of the off-shore fishermen possessing sea-going boats. If the public fish supply were to benefit greatly by such legislation it might be, on the whole, expedient that a few fishermen should suffer for the advantage of the nation; but we should like to be quite certain that the benefit would be very great compared with the suffering. These, however, are economic questions which do not quite come within the scope of a strictly scientific report.

It must not be forgotten that the settlement of the

question, for or against a 6-inch mesh, may depend on future investigation. If the fish measurements carried out during 1909 are repeated, on at least an equally large scale in 1914, say, and if there were to be a significant decrease in the average and modal sizes of plaice caught by means of a 6-inch trawl-net in that year, then the whole question will be looked at from quite another aspect, and restriction of the powers of capture might be conceivably necessary.

7. SIZES AT SEXUAL MATURITY.

Mature plaice are commoner in in-shore Lancashire waters than snakes are in Iceland, but one cannot say much more than this. Of some 2,500 plaice dissected in the Liverpool and Piel Laboratory less than 50 were identified as sexually mature. Spawning plaice are not found in in-shore waters, and nowhere in the whole Irish Sea in relative abundance except on the fishing grounds about and between the Selker and Bahama Light Vessels. Doubtless they exist elsewhere, but in very small numbers; and it is quite likely that the majority of the young plaice inhabiting the nurseries on the Lancashire and Cheshire coasts are spawned to the South-West, in the St. George's Channel and in the large Welsh bays. Probably by much the smaller proportion comes from the spawning grounds between Cumberland and the North end of the Isle of Man.

In the late summer and autumn large mature plaice immigrate for a month or two into shallow waters, and such fish may be taken in Barrow Channel, Morecambe Bay, in the Ribble, and off the coasts and in the estuaries of North Wales. It is mainly such fish that are handled in the samples reaching us. The numbers are too small to be treated statistically.

It is to be noted, however, that comparatively small plaice have been found to be sexually mature. Some females of 29·5 to 30·5 cms. (12 inches) were spawning fish, and a fairly large proportion of male fish from 25 to 30 cms. (10-12 inches) long were mature and had fully developed testes. This was the most novel part of this section of the investigation. We had not previously suspected that sexually mature plaice were so small as the above figures indicate. The ages of these male plaice were over three and less than four years. The mature females were very seldom less than four years old. It has been suggested by Kyle that on intensely fished grounds the average size of plaice, when they first become mature, is becoming less, and this hypothesis is very probable. But another reason may well be that we simply have not looked for these plaice in former years.

TABLES.—SIZES OF PLAICE TAKEN FROM THE SIX-INCH TRAWL-NET, AND OTHER DATA.

Luce Bay and Firth of Clyde

Mean Length.	Off Corsewall Point, Firth of Clyde. 6″ June.		Luce Bay. 6½″ Oct.		Mean Length.	Off Corsewall Point, Firth of Clyde. 6″ June.		Luce Bay. 6½″ Oct.	
	No.	%	No.	%		No.	%	No.	%
10·5	—	—	1	0·06	34·5	1	—	40	2·42
11·5	—	—	—	—	35·5	3	—	30	1·82
12·5	—	—	1	0·06	36·5	2	—	27	1·64
13·5	—	—	—	—	37·5	4	—	19	1·15
14·5	—	—	3	0·18	38·5	4	—	22	1·33
15·5	—	—	17	1·03	39·5	6	—	13	0·79
16·5	—	—	53	3·21	40·5	3	—	9	0·54
17·5	—	—	71	4·30	41·5	5	—	10	0·61
18·5	—	—	136	8·25	42·5	2	—	7	0·42
19·5	—	—	119	7·21	43·5	2	—	3	0·18
20·5	—	—	134	8·13	44·5	1	—	9	0·54
21·5	—	—	102	6·19	45·5	—	—	1	0·06
22·5	—	—	91	5·52	46·5	—	—	3	0·18
23·5	—	—	82	4·97	47·5	—	—	4	0·24
24·5	—	—	88	5·33	48·5	—	—	2	0·12
25·5	—	—	84	5·09	49·5	—	—	1	0·06
26·5	—	—	84	5·09	50·5	—	—	1	0·06
27·5	—	—	78	4·73	51·5	—	—	1	0·06
28·5	—	—	54	3·27	52·5	—	—	—	—
29·5	—	—	59	3·58	53·5	—	—	1	0·06
30·5	—	—	54	3·27					
31·5	—	—	37	2·24					
32·5	1	—	53	3·21	Total	35	—	1649	99·93
33·5	1	—	45	2·73					

Mean Length.	Near Duddon Banks, 1909, 6″ trawl-mesh								Near Bahama Bank and towards Selker Light Vessel, 1909, 6″ trawl-mesh		
	March.		April.		May.		November.		January.	February.	March.
	No.	%	No.	%	No.	%	No.	%	No.	No.	No.
10·5	5	0·52	1	0·17	—	—	—	—	—	—	—
11·5	4	0·42	1	0·17	—	—	—	—	—	—	—
12·5	5	0·52	—	—	—	—	—	—	—	—	—
13·5	5	0·52	2	0·34	—	—	—	—	—	—	—
14·5	24	2·52	8	1·33	1	0·84	—	—	—	—	—
15·5	43	4·48	22	3·66	1	0·84	1	0·27	—	—	1
16·5	83	8·73	41	6·83	3	2·52	3	0·80	—	—	—
17·5	130	13·67	61	10·16	8	6·72	21	5·60	2	—	1
18·5	171	17·99	118	19·66	40	33·62	22	5·86	—	—	3
19·5	149	15·67	111	18·49	25	21·01	21	5·60	2	1	3
20·5	117	12·30	71	11·83	19	15·97	20	5·33	2	2	2
21·5	78	8·20	48	8·00	12	10·09	7	1·86	6	2	3
22·5	48	5·05	36	6·00	3	2·52	10	2·67	4	5	7
23·5	36	3·78	31	5·16	2	1·68	16	4·26	5	2	—
24·5	19	2·00	16	2·66	—	—	27	7·17	9	7	2
25·5	12	1·26	9	1·50	1	0·84	44	11·73	5	6	3
26·5	10	1·06	5	0·83	1	0·84	41	10·93	8	6	4
27·5	5	0·52	2	0·33	1	0·84	37	9·87	5	6	5
28·5	5	0·52	4	0·66	2	1·68	29	7·73	4	5	3
29·5	1	0·10	13	2·13	—	—	27	7·17	3	5	2
30·5	—	—	—	—	—	—	23	6·13	2	3	3
31·5	—	—	—	—	—	—	12	3·20	3	6	3
32·5	1	0·10	—	—	—	—	8	2·13	3	2	—
33·5	—	—	—	—	—	—	3	0·80	1	4	2
34·5	—	—	—	—	—	—	2	0·52	2	—	2
35·5	—	—	—	—	—	—	1	0·27	2	1	—
36·5	—	—	—	—	—	—	—	—	3	1	1
37·5	—	—	—	—	—	—	—	—	—	1	—
38·5	—	—	—	—	—	—	—	—	1	2	2
39.5	—	—	—	—	—	—	—	—	—	1	5
40·5	—	—	—	—	—	—	—	—	2*	1	3
Total ...	951	99·93	600	99·91	119	100·01	375	99·90	74	69	60

* 41 and 45 cms.

Fleetwood Channel, 1909, 6″ trawl-mesh.

Mean Length.	February.		March.		June.		July		August.		September.		December.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
12·5	—	—	—	—	—	—	—	—	—	—	—	—	1	0·40
13·5	—	—	—	—	—	—	1	0·33	—	—	—	—	2	0·80
14·5	2	4·54	2	1·96	1	0·20	2	0·67	1	0·42	1	0·49	—	—
15·5	8	18·18	5	4·90	17	3·52	11	3·68	5	2·10	1	0·49	4	1·61
16·5	7	15·91	14	13·73	25	5·18	15	5·02	3	1·26	7	3·48	18	7·25
17·5	10	22·73	16	15·69	59	12·25	30	10·03	12	5·04	8	3·98	38	15·32
18·5	1	2·27	19	18·63	77	15·98	28	9·36	24	10·08	17	8·46	46	18·55
19·5	3	6·82	8	7·84	59	12·25	34	11·37	28	11·77	21	10·45	42	16·93
20·5	2	4·54	13	12·75	62	12·86	39	13·04	29	12·18	23	11·44	22	8·87
21·5	2	4·54	7	6·86	51	10·58	37	12·37	40	16·81	26	12·93	14	5·64
22·5	3	6·82	6	5·88	45	9·33	34	11·37	25	10·51	23	11·44	19	7·66
23·5	2	4·54	7	6·86	31	6·43	32	10·70	23	9·66	35	17·42	10	4·03
24·5	1	2·27	1	0·98	19	3·94	13	4·35	23	9·66	19	9·45	12	4·84
25·5	2	4·54	3	2·94	14	2·90	13	4·35	12	5·04	7	3·48	6	2·42
26·5	—	—	1	0·98	11	2·28	4	1·33	5	2 10	7	3·48	6	2·42
27·5	—	—	—	—	7	1·45	4	1·33	2	0·82	3	1·47	2	0·80
28·5	—	—	—	—	1	0·20	2	0·67	5	2·10	1	0·49	1	0·40
29·5	—	—	—	—	1	0·20	—	—	1	0·42	2	0·98	3	1·20
30·5	1	2·27	—	—	—	—	—	—	—	—	—	—	1	0·40
31·5	—	—	—	—	1	0·20	—	—	—	—	—	—	1	0·40
38·5	—	—	—	—	1	0·20	—	—	—	—	—	—	—	—
Total ...	44	99·97	102	100·00	482	99·95	299	99·97	238	99·97	201	99·93	248	99·94

Barrow Channel, 1909, 6″ trawl-mesh

Mean Length.	January.		February.		March.		April.		May.		June.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	—	—	—	—
12·5	—	—	—	—	—	—	—	—	—	—	—	—
13·5	—	—	—	—	—	—	—	—	—	—	—	—
14·5	—	—	1	3·03	2	2·89	1	1·96	—	—	2	0·74
15·5	2	2·29	3	9·09	9	13·04	4	7·84	7	7·95	7	2·59
16·5	17	19·54	5	15·16	12	17·40	11	21·57	16	18·18	13	4·81
17·5	18	20·69	10	30·31	18	26·09	18	35·30	17	19·32	23	8·52
18·5	16	18·40	6	18·19	14	20·29	8	15·68	14	15·90	48	17·77
19·5	12	13·79	1	3·03	4	5·79	4	7·84	15	17·04	43	15·92
20·5	4	4·59	2	6·06	4	5·79	5	9·80	7	7·95	39	14·44
21·5	3	3·44	2	6·06	2	2·89	—	—	6	6·82	34	12·59
22·5	3	3·44	1	3,03	2	2·89	—	—	1	1·13	19	7·04
23·5	4	4·59	1	3·03	2	2·89	—	—	2	2·26	22	8·12
24·5	2	2·29	1	3·03	—	—	—	—	3	3·40	9	3·33
25·5	—	—	—	—	—	—	—	—	—	—	5	1·85
26·5	3	3·44	—	—	—	—	—	—	—	—	3	1·11
27·5	2	2·29	—	—	—	—	—	—	—	—	3	1·11
28·5	—	—	—	—	—	—	—	—	—	—	—	—
29·5	—	—	—	—	—	—	—	—	—	—	—	—
30·5	1	1·15	—	—	—	—	—	—	—	—	—	—
Total ...	87	99·94	33	100·02	69	99·96	51	99·99	88	99·95	270	99·94

Barrow Channel, 1909, 6″ trawl-mesh (*continued*)

Mean Length.	July.		August.		October.		November.		December.	
	No.	%	No.	%	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	—	—
12·5	—	—	—	—	—	—	—	—	—	—
13·5	—	—	—	—	—	—	—	—	—	—
14·5	—	—	—	—	—	—	—	—	1	0·57
15·5	—	—	7	0·88	1	0·59	4	1·84	4	2·27
16·5	1	0·86	10	1·27	10	5·95	10	4·61	21	11·93
17·5	—	—	13	1·65	16	9·52	40	18·43	28	15·92
18·5	3	2·58	21	2·66	21	12·50	38	17·51	28	15·92
19·5	3	2·58	28	3·55	17	10·12	21	9·68	10	5·68
20·5	5	4·31	54	6·85	17	10·12	22	10·14	22	12·50
21·5	4	3·45	51	6·47	13	7·74	16	7·37	14	7·95
22·5	15	12·93	119	15·10	11	6·55	23	10·59	11	6·25
23·5	15	12·93	105	13·32	12	7·14	13	5·99	11	6·25
24·5	21	18·10	99	12·56	11	6·55	9	4·14	7	3·97
25·5	19	16·38	103	13·07	9	5·35	3	1·38	6	3·41
26·5	12	10·35	68	8·63	8	4·76	2	0·92	4	2·27
27·5	9	7·76	60	7·60	7	4·17	7	3·22	4	2·27
28·5	5	4·31	22	2·79	4	2·38	3	1·38	3	1·70
29·5	2	1·72	13	1·65	4	2·38	3	1·38	1	0·57
30·5	—	—	9	1·14	3	1·78	2	0·92	1	0·57
31·5	—	—	3	0·38	—	—	—	—	—	—
32·5	1	0·86	2	0·25	3	1·78	—	—	—	—
33·5	1	0·86	1	0·13	1	0·60	1	0·46	—	—
34·5	—	—	—	—	—	—	—	—	—	—
35·5	—	—	—	—	—	—	—	—	—	—
36·5	—	—	—	—	—	—	—	—	—	—
37·5	—	—	—	—	—	—	—	—	—	—
38·5	—	—	—	—	—	—	—	—	—	—
39·9	—	—	—	—	—	—	—	—	—	—
40·5	—	—	—	—	—	—	—	—	—	—
Total ...	116	99·98	788	99·95	168	99·98	217	99·96	176	100·00

Near Nelson Buoy; Blackpool Closed Ground, 1909, 6″ trawl-mesh

Mean Length.	March.		May.		June.		July.		August.		September.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
11·5	—	—	—	—	—	—	—	—	—	—	1	0·11
12·5	2	1·06	—	—	—	—	—	—	1	0·44	1	0·11
13·5	7	3·70	—	—	1	0·10	—	—	4	1·78	4	0·44
14·5	7	3·70	—	—	8	0·80	—	—	3	1·33	13	1·44
15·5	34	17·99	4	1·38	28	2·80	2	1·17	14	6·22	56	6·21
16·5	38	20·11	9	3·11	63	6·32	5	2·92	22	9·80	110	12·20
17·5	27	14·28	9	3·11	116	11·64	5	2·92	38	16·89	178	19·73
18·5	11	5·82	24	8·31	169	16·96	16	9·35	23	10·21	127	14·08
19·5	7	3·70	34	11·76	137	13·75	29	16·96	26	11·55	98	10·86
20·5	3	1·59	32	11·07	122	12·24	22	12·86	27	12·00	67	7·43
21·5	14	7·41	40	13·84	122	12·24	28	16·38	17	7·55	59	6·54
22·5	8	4·23	27	9·34	103	10·34	25	14·62	18	8·00	51	5·56
23·5	9	4·76	31	10·73	71	7·13	18	10·53	12	5·33	31	3·52
24·5	8	4·23	24	8·31	29	2·91	9	5·26	9	4·00	25	2·78
25·5	8	4·23	16	5·54	12	1·20	4	2·34	3	1·33	22	2·44
26·5	6	3·17	16	5·54	4	0·40	2	1·17	1	0·44	15	1·66
27·5	—	—	12	4·15	3	0·30	3	1·75	3	1·33	14	1·55
28·5	—	—	5	1·73	1	0·10	—	—	1	0·44	8	0·88
29·5	—	—	2	0·70	4	0·40	1	0·60	1	0·44	5	0·56
30·5	—	—	3	1·04	1	0·10	1	0·60	1	0·44	6	0·66
31·5	—	—	1	0·34	—	—	—	—	—	—	3	0·33
32·5	—	—	—	—	2	0·20	—	—	—	—	3	0·33
33·5	—	—	—	—	—	—	1	0·60	1	0·44	1	0·11
34·5	—	—	—	—	—	—	—	—	—	—	1	0·11
35·5	—	—	—	—	—	—	—	—	—	—	1	0·11
40·5	—	—	—	—	—	—	—	—	—	—	2	0·22
Total...	189	99·98	289	100·00	996	99·93	171	100·03	225	99·96	902	99·97

Rock Channel, 1909, 6″ trawl-mesh

Mean Length.	March.		April.		May.		June.		July.		September.		October.		November.		December.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
10·5	—	—	1	0·05	—	—	—	—	1	0·08	—	—	—	—	—	—	—	—
11·5	2	0·1	6	0·31	—	—	5	0·20	—	—	—	—	—	—	—	—	—	—
12·5	6	0·3	12	0·63	1	0·13	7	0·34	6	0·51	—	—	—	—	—	—	—	—
13·5	39	2·0	26	1·36	7	0·90	26	1·22	5	0·42	—	—	—	—	—	—	—	—
14·5	122	6·24	80	4·20	53	6·81	123	6·01	50	4·25	4	0·71	4	3·74	—	—	—	—
15·5	335	17·16	266	13·93	118	15·17	495	24·20	180	15·30	9	1·61	9	8·41	—	—	1	2·13
16·5	441	22·59	406	21·26	132	17·00	521	25·47	356	30·27	30	5·37	23	21·49	2	3·12	1	2·13
17·5	342	17·51	495	25·93	110	14·14	285	13·93	276	23·47	98	17·56	18	16·82	6	9·37	3	6·38
18·5	219	11·22	226	11·84	103	13·23	154	7·58	152	12·94	150	26·88	16	14·95	10	15·63	6	12·76
19·5	144	7·37	148	7·75	99	12·72	118	5·77	86	7·31	92	16·48	13	12·14	14	21·87	9	19·15
20·5	105	5·38	99	5·18	77	9·90	140	6·85	21	1·79	78	13·98	8	7·48	12	18·74	7	14·89
21·5	69	3·53	46	2·41	50	6·42	85	4·15	18	1·53	47	8·42	10	9·35	16	25·00	5	10·64
22·5	42	2·15	39	2·00	14	1·80	50	2·45	11	0·94	28	5·02	3	2·80	2	3·12	9	19·15
23·5	32	1·63	24	1·26	9	1·15	23	1·12	9	0·77	11	1·97	1	0·93	1	1·56	2	4·26
24·5	20	1·02	18	0·94	3	0·40	8	0·39	2	0·17	4	0·71	1	0·93	1	1·56	1	2·13
25·5	13	0·66	9	0·47	2	0·25	3	0·14	2	0·17	4	0·71	—	—	—	—	3	6·38
26·5	8	0·41	4	0·20	—	—	1	0·05	1	0·08	2	0·36	—	—	—	—	—	—
27·5	9	0·46	2	0·10	—	—	1	0·05	—	—	1	0·18	—	—	—	—	—	—
28·5	3	0·15	1	0·05	—	—	—	—	—	—	—	—	1	0·93	—	—	—	—
29·5	1	0·05	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
30·5	—	—	1	0·05	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total...	1952	99·93	1909	99·92	778	100·02	2045	99·92	1176	100·00	558	99·96	107	99·97	64	99·97	47	100·00

Horse Channel, 1909, 6″ trawl-mesh

Mean length.	June.		July.		August.*	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	—	—	2	0·14
13·5	—	—	1	0·12	17	1·20
14·5	8	1·42	21	2·47	56	3·97
15·5	44	7·80	26	3·05	88	6·24
16·5	84	14·89	67	7·88	122	8·65
17·5	80	14·18	93	10·93	151	10·71
18·5	86	15·24	103	12·10	140	9·92
19·5	75	13·28	112	13·16	138	9·79
20·5	68	12·05	123	14·46	139	9·86
21·5	53	9·40	105	12·33	117	8·29
22·5	35	6·20	85	10·00	122	8·65
23·5	14	2·48	61	7·16	104	7·37
24·5	8	1·42	20	2·35	96	6·82
25·5	3	0·53	9	1·06	53	3·76
26·5	3	0·53	6	0·70	31	2·19
27·5	1	0·17	4	0·47	24	1·70
28·5	1	0·17	7	0·82	5	0·35
29·5	1	0·17	—	—	3	0·21
30·5	—	—	—	—	2	0·14
31·5	—	—	2	0·23	—	—
32·5	—	—	1	0·12	—	—
33·5	—	—	1	0·12	—	—
34·5	—	—	—	—	—	—
35·5	—	—	—	—	—	—
36·5	—	—	1	0·12	—	—
37·5	—	—	—	—	—	—
38·5	—	—	—	—	—	—
39·5	—	—	2	0·23	—	—
40·5	—	—	1	0·12	—	—
Total	564	99·93	851	100·00	1410	99·96

* Part of catch lost through tearing of net.

Horse Channel, 1909, 6″ trawl-mesh—*Continued*

Mean length.	September.		October.		November.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	—	—	—	—
13·5	1	0·09	—	—	—	—
14·5	4	0·39	—	—	—	—
15·5	5	0·48	—	—	—	—
16·5	29	2·83	4	1·76	12	3·34
17·5	90	8·79	16	7·05	30	8·35
18·5	99	9·67	30	13·21	48	13·36
19·5	99	9·67	31	13·67	67	18·66
20·5	123	12·01	24	10·57	47	13·09
21·5	118	11·53	28	12·34	37	10·30
22·5	107	10·46	16	7·05	39	10·86
23·5	76	7·42	17	7·49	37	10·30
24·5	75	7·32	13	5·73	13	3·62
25·5	58	5·66	14	6·17	12	3·34
26·5	55	5·37	11	4·84	7	1·95
27·5	30	2·93	6	2·64	2	0·55
28·5	28	2·73	7	3·08	3	0·83
29·5	14	1·36	5	2·20	2	0·55
30·5	5	0·48	2	0·88	2	0·55
31·5	7	0·68	—	—	1	0·28
32·5	1	0·09	—	—	—	—
33·5	1	0·09	—	—	—	—
34·5	1	0·09	1	0·44	—	—
35·5	—	—	—	—	—	—
36·5	—	—	—	—	—	—
37·5	—	—	1	0·44	—	—
38·5	—	—	—	—	—	—
39·5	—	—	—	—	—	—
40·5	—	—	1	0·44	—	—
Total	1026	100·14	227	100·00	359	99·93

Near Mersey Bar, 1909, 6″ trawl-mesh

Mean Length.	June.		July.		September.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	1	0·42	5	1·36
13·5	1	0·21	1	0·42	6	1·63
14·5	—	—	3	1·26	16	4·36
15·5	5	1·07	6	2·52	31	8·44
16·5	15	3·18	15	6·30	41	11·17
17·5	43	9·13	29	12·19	49	13·36
18·5	55	11·67	18	7·56	32	8·72
19·5	59	12·52	34	14·28	30	8·17
20·5	74	15·71	36	15·13	28	7·63
21·5	55	11·67	36	15·13	18	4·91
22·5	43	9·13	25	10·50	26	7·09
23·5	29	6·15	13	5·46	18	4·91
24·5	26	5·52	10	4·20	16	4·36
25·5	14	3·00	5	2·10	10	2·72
26·5	7	1·48	3	1·26	8	2·18
27·5	12	2·55	1	0·42	13	3·54
28·5	9	1·91	1	0·42	4	1·09
29·5	8	1·70	1	0·42	5	1·36
30·5	6	1·27	—	—	4	1·09
31·5	2	0·42	—	—	2	0·55
32·5	3	0·64	—	—	2	0·55
33·5	2	0·42	—	—	1	0·27
34·5	—	—	—	—	2	0·55
35·5	—	—	—	—	—	—
36·5	—	—	—	—	—	—
37·5	1	0·21	—	—	—	—
38·5	1	0·21	—	—	—	—
39·5	—	—	—	—	—	—
40·5	1	0·21	—	—	—	—
Total......	471	99·98	238	99·99	367	100·01

Mersey Area, 1909, $\frac{1}{2}''$ trawl-mesh.

Mean	January.		February.		March.		April.		May.		September.		November.	
Length.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
4·5	113	2·23	51	1·56	4	2·56	5	0·65	—	—	2	0·34	33	1·30
5·5	1168	23·09	521	16·00	21	13·50	107	14·00	—	—	36	6·22	531	20·96
6·5	1487	29·40	684	20·96	31	19·87	149	19·47	—	—	140	24·17	481	19·23
7·5	920	18·19	671	20·56	10	6·41	257	33·59	—	—	138	23·83	426	16·82
8·5	601	11·88	668	20·47	14	9·00	98	12·81	8	9·31	85	14·68	355	14·02
9·5	401	7·93	202	6·13	11	7·00	29	3·79	5	5·81	37	6·39	195	7·69
10·5	168	3·32	94	2·88	5	3·20	27	3·53	5	5·81	24	4·14	111	4·38
11·5	80	1·58	41	1·26	6	3·84	1	0·13	8	9·31	18	3·11	97	3·83
12·5	36	0·71	61	1·87	7	4·50	2	0·26	14	16·28	24	4·14	52	2·05
13·5	30	0·59	30	0·92	5	3·20	—	—	5	5·81	23	3·97	40	1·58
14·5	16	0·31	58	1·77	10	6·41	6	0·78	5	5·81	15	2·59	38	1·50
15·5	16	0·31	60	1·83	6	3·84	8	1·04	7	8·14	6	1·03	36	1·42
16·5	10	0·20	42	1·28	12	7·70	18	2·36	10	11·62	8	1·38	44	1·74
17·5	7	0·13	28	0·85	4	2·56	19	2·48	9	10·47	9	1·56	35	1·38
18·5	1	0·02	15	0·46	3	1·90	20	2·63	5	5·81	5	0·86	16	0·63
19·5	3	0·05	13	0·39	3	1·90	16	2·09	3	3·49	5	0·86	14	0·55
20·5	—	—	11	0·33	2	1·30	—	—	1	1·16	3	0·52	12	0·47
21·5	—	—	8	0·24	—	—	2	0·26	1	1·16	—	—	10	0·39
22·5	—	—	2	0·06	1	0·65	1	0·13	—	—	—	—	4	0·02
23·5	—	—	2	0·06	1	0·65	—	—	—	—	—	—	2	0·01
24·5	—	—	1	0·03	—	—	—	—	—	—	1	0·17	—	—
25·5	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Total...	5057	99·94	3263	99·91	156	99·99	765	100·00	86	99·99	579	99·96	2533	99·97

Mersey Area, 1909, 4″ trawl-mesh

Mean Length.	Rock Channel.		Horse Channel.				Mersey Bar.	
	August.		August.		September.		August.	
	No.	%	No.	%	No.	%	No.	%
10·5	—	—	1	0·07	—	—	—	—
11·5	—	—	—	—	—	—	—	—
12·5	3	0·63	3	0·22	9	0·77	1	0·32
13·5	26	5·51	14	1·05	30	2·56	12	3·87
14·5	58	12·28	50	3·78	112	9·57	41	13·22
15·5	97	20·55	101	7·62	178	15·22	44	14·19
16·5	85	18·01	133	10·07	151	12·90	49	15·81
17·5	71	15·04	135	10·19	111	9·49	25	8·06
18·5	47	9·96	150	11·29	78	6·67	21	6·78
19·5	29	6·14	103	7·77	58	4·95	12	3·87
20·5	21	4·45	116	8·75	65	5·55	32	10·32
21·5	13	2·75	114	8·60	70	5·98	23	7·42
22·5	12	2·55	147	11·09	61	5·21	22	7·09
23·5	3	0·63	120	9·06	53	4·53	10	3·22
24·5	2	0·42	59	4·45	54	4·61	8	2·58
25·5	2	0·42	36	2·72	58	4·96	6	1·94
26·5	1	0·21	15	1·13	30	2·56	—	—
27·5	1	0·21	10	0·75	24	2·05	2	0·64
28·5	1	0·21	2	0·15	14	1·19	—	—
29·5	—	—	10	0·75	6	0·51	—	—
30·5	—	—	1	0·07	6	0·51	—	—
31·5	—	—	1	0·07	—	—	1	0·32
32·5	—	—	2	0·14	1	0·08	1	0·32
33·5	—	—	1	0·07	—	—	—	—
34·5	—	—	—	—	—	—	—	—
35·5	—	—	—	—	—	—	—	—
36·5	—	—	—	—	1	0·08	—	—
37·5	—	—	—	—	—	—	—	—
38·5	—	—	1	0·07	—	—	—	—
39·5	—	—	—	—	—	—	—	—
40·5	—	—	—	—	—	—	—	—
Total...	472	99·97	1325	99·93	1170	99·95	310	99·97

Horse Channel and No. 6 Station, 1909, 7″ trawl-mesh

Mean Length.	September.		October.		November.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	—	—	—	—
13·5	—	—	—	—	—	—
14·5	1	0·08	—	—	—	—
15·5	2	0·17	1	0·73	1	0·28
16·5	8	0·69	8	5·88	2	0·57
17·5	29	2·48	27	19·86	30	8·59
18·5	54	4·63	29	21·32	68	19·48
19·5	108	9·25	18	13·23	63	18·05
20·5	138	11·82	6	4·41	54	15·47
21·5	113	9·68	11	8·09	38	10·89
22·5	115	9·85	6	4·41	29	8·31
23·5	119	10·20	5	3·68	24	6·87
24·5	146	12·51	2	1·46	7	2·00
25·5	110	9·43	6	4·41	11	3·15
26·5	82	7·03	4	2·94	10	2·86
27·5	63	5·40	3	2·19	1	0·28
28·5	35	3·00	4	2·94	7	2·00
29·5	17	1·42	3	2·19	2	0·57
30·5	7	0·60	2	1·46	—	—
31·5	4	0·34	1	0·73	—	—
32·5	11	0·94	—	—	1	0·28
33·5	3	0·25	—	—	1	0·28
34·5	2	0·17	—	—	—	—
35·5	—	—	—	—	—	—
36·5	—	—	—	—	—	—
37·5	—	—	—	—	—	—
38·5	—	—	—	—	—	—
39·5	—	—	—	—	—	—
40·5	—	—	—	—	—	—
Total...	1167	99·94	136	99·93	349	99·93

Beaumaris and Conway Bays, 1909, 6″ trawl-mesh

Mean length.	June.		July.		September.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	2	0·12
12·5	—	—	2	0·26	6	0·37
13·5	—	—	1	0·13	6	0·37
14·5	—	—	3	0·39	17	1·04
15·5	1	0·67	24	3·16	24	1·47
16·5	10	6·75	37	4·88	73	4·46
17·5	16	10·81	87	11·48	104	6·36
18·5	19	12·83	101	13·32	104	6·36
19·5	27	18·24	116	15·31	124	7·59
20·5	18	12·16	93	12·27	107	6·54
21·5	16	10·81	94	12·40	87	5·32
22·5	17	11·48	57	7·52	112	6·85
23·5	7	4·73	43	5·67	122	7·46
24·5	1	0·67	37	4·88	121	7·40
25·5	2	1·35	18	2·37	116	7·10
26·5	2	1·35	7	0·92	123	7·52
27·5	4	2·70	4	0·53	96	5·87
28·5	2	1·35	6	0·79	99	6·05
29·5	2	1·35	6	0·79	53	3·24
30·5	—	—	7	0·92	41	2·51
31·5	—	—	—	—	33	2·02
32·5	2	1·35	1	0·13	21	1·28
33·5	—	—	3	0·39	14	0·86
34·5	1	0·67	4	0·53	10	0·61
35·5	—	—	2	0·26	6	0·37
36·5	1	0·67	2	0·26	4	0·24
37·5	—	—	—	—	4	0·24
38·5	—	—	3	0·39	1	0·06
39·5	—	—	—	—	1	0·06
40·5	—	—	—	—	4	0·24
Total	148	99·94	758	99·95	1635	99·98

Beaumaris and Conway Bays, 1909, 6″ trawl-mesh—*Continued*

Mean Length	October.		November.		December.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	1	0·06	—	—	1	0·29
13·5	5	0·29	2	0·14	1	0·29
14·5	14	0·81	6	0·42	2	0·58
15·5	27	1·57	28	1·97	4	1·17
16·5	78	4·53	69	4·87	13	3·80
17·5	143	8·30	103	7·27	14	4·09
18·5	137	7·95	102	7·20	13	3·80
19·5	106	6·15	88	6·21	17	4·97
20·5	88	5·11	77	5·43	20	5·85
21·5	83	4·81	89	6·28	21	6·14
22·5	77	4·47	75	5·29	25	7·31
23·5	103	5·98	89	6·28	26	7·60
24·5	102	5·92	121	8·54	27	7·89
25·5	125	7·25	127	8·96	25	7·31
26·5	154	8·94	102	7·20	19	5·56
27·5	122	7·08	89	6·28	16	4·68
28·5	115	6·67	81	5·72	12	3·52
29·5	93	5·40	54	3·81	13	3·80
30·5	63	3·65	40	2·82	16	4·68
31·5	40	2·32	26	1·79	17	4·97
32·5	19	1·10	20	1·41	11	3·22
33·5	14	0·81	7	0·49	5	1·47
34·5	6	0·35	3	0·21	2	0·58
35·5	2	0·12	3	0·21	4	1·17
36·5	2	0·12	6	0·42	5	1·46
37·5	1	0·06	—	—	2	0·58
38·5	2	0·12	2	0·14	4	1·17
39·5	1	0·06	2	0·14	4	1·17
40·5	—	—	6	0·42	3	0·87
Total	1723	100·00	1417	99·92	342	99·99

Red Wharf Bay, 1909, 6″ trawl-mesh

Mean Length.	June.		July.		August.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	—	—	—	—
13·5	—	—	—		—	—
14·5	1	0·68	1	0·34	—	—
15·5	2	1·36	—	—	1	0·60
16·5	8	5·44	4	1·37	1	0·60
17·5	18	12·25	9	3·09	8	4·76
18·5	18	12·25	16	5·50	8	4·76
19·5	26	17·69	27	9·28	18	10·72
20·5	9	6·12	40	13·74	11	6·55
21·5	8	5·44	42	14·43	25	14·88
22·5	9	6·12	39	13·41	32	19·04
23·5	9	6·12	26	8·93	17	10·12
24·5	6	4·08	22	7·56	17	10·12
25·5	4	2·72	14	4·81	9	5·34
26·5	5	3·40	12	4·12	7	4·16
27·5	3	2·04	8	2·75	3	1·78
28·5	4	2·72	3	1·03	1	0·60
29·5	3	2·04	5	1·72	3	1·78
30·5	2	1·36	4	1·37	1	0·60
31·5	3	2·04	6	2·06	2	1·20
32·5	—	—	4	1·37	1	0·60
33·5	3	2·04	2	0·68	2	1·20
34·5	1	0·68	2	0·68	1	0·60
35·5	—	—	—	—	—	—
36·5	2	1·36	1	0·34	—	—
37·5	—	—	—	—	—	—
38·5	1	0·68	1	0·34	—	—
39·5	1	0·68	1	0·34	—	—
40·5	1	0·68	2	0·68	—	—
Total...	147	99·99	291	99·94	168	100·01

Red Wharf Bay, 1909, 6″ trawl-mesh—*Continued*

Mean Length.	October.		November.		December.	
	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—
11·5	—	—	—	—	—	—
12·5	—	—	—	—	—	—
13·5	1	0·90	1	0·20	1	0·09
14·5	3	2·70	1	0·20	7	0·60
15·5	2	1·80	6	1·22	23	1·99
16·5	3	2·70	10	2·04	61	5·29
17·5	7	6·30	13	2·65	68	5·90
18·5	8	7·20	25	5·09	60	5·20
19·5	6	5·40	32	6·51	51	4·42
20·5	9	8·10	43	8·76	46	3·99
21·5	5	4·50	33	6·72	54	4·68
22·5	5	4·50	53	10·79	58	5·03
23·5	10	9·00	40	8·16	73	6·33
24·5	6	5·40	46	9·37	81	7·02
25·5	10	9·00	50	10·20	77	6·68
26·5	11	9·91	25	5·10	71	6·16
27·5	3	2·70	26	5·29	66	5·72
28·5	5	4·50	24	4·90	76	6·59
29·5	3	2·70	15	3·05	65	5·63
30·5	5	4·50	17	3·46	49	4·25
31·5	3	2·70	15	3·05	42	3·64
32·5	3	2·70	5	1·02	49	4·25
33·5	1	0·90	3	0·61	28	2·43
34·5	1	0·90	3	0·61	13	1·13
35·5	—	—	2	0·40	13	1·13
36·5	—	—	—	—	5	0·44
37·5	1	0·90	—	—	4	0·36
38·5	—	—	3	0·61	2	0·18
39·5	—	—	—	—	1	0·09
40·5	—	—	—	—	9	0·78
Total...	111	99·91	491	100·01	1153	100·00

Cardigan Bay, 1909, 6″ trawl-mesh

Mean Length.	Near Patches Buoy.			Near New Quay Head.						
	Jan.	Feb.	Mar.	February.		Mar.	April.		May.	
	No.	No.	No.	No.	%	No.	No.	%	No.	%
16·5	—	—	1	—	—	4	3	4·41	3	0·69
17·5	—	—	2	—	—	1	6	8·82	26	6·05
18·5	—	4	1	—	—	1	—	—	29	6·74
19·5	—	—	1	1	2·5	1	6	8·82	35	8·14
20·5	—	1	1	2	5·0	2	2	2·94	40	9·30
21·5	1	1	1	1	2·5	2	2	2·94	34	7·90
22·5	1	—	6	—	—	7	7	10·29	25	5·81
23·5	3	2	—	—	—	2	5	7·35	35	8·14
24·5	1	8	—	3	7·5	2	11	16·17	24	5·58
25·5	2	4	4	3	7·5	15	7	10·29	28	6·51
26·5	5	7	7	4	10·0	9	6	8·82	46	10·70
27·5	2	6	5	—	—	5	3	4·41	24	5·58
28·5	6	9	7	4	10·0	11	2	2·94	33	7·67
29·5	5	10	13	4	10·0	6	2	2·94	30	6·98
30·5	5	6	11	2	5·0	8	4	5·88	11	2·56
31·5	1	7	12	3	7·5	4	1	1·47	5	1·16
32·5	4	7	8	2	5·0	5	—	—	1	0·23
33·5	2	5	10	—	—	2	—	—	—	—
34·5	1	4	6	4	10·0	1	—	—	1	0·23
35·5	4	3	5	1	2·5	1	—	—	—	—
36·5	2	1	4	1	2·5	3	1	1·47	—	—
37·5	3	2	3	1	2·5	3	—	—	—	—
38·5	—	2	2	—	—	3	—	—	—	—
39·5	1	2	3	1	2·5	—	—	—		—
40·5	—	—	1	1	2·5	1	—	—	—	—
41·5	—	—	2	—	—	—	—	—	—	—
42·5	—	—	1	—	—	1	—	—	—	—
43·5	—	—	1	—	—	—	—	—	—	—
44·5	—	3	1	1	2·5	—	—	—	—	—
45·5	—	1	3	—	—	—	—	—	—	—
46·5	1	2*	2**	1	2·5	—	—	—	—	—
Total...	50	97	124	40	100·0	100	68	99·96	430	99·97

* 1 at 52 and 1 at 61. ** 53 and 60.

Near New Quay Head

Mean Length.	June.		Mean Length.	June.	
	No.	%		No.	%
16·5	5	2·30	28·5	30	13·82
17·5	8	3·69	29·5	3	1·38
18·5	14	6·45	30·5	4	1·84
19·5	18	8·29	31·5	1	0·46
20·5	27	12·45	32·5	—	—
21·5	23	10·59	33·5	—	—
22·5	19	8·75	34·5	—	—
23·5	15	6·90	35·5	—	—
24·5	12	5·53	36·5	—	—
25·5	15	6·90	37·5	1	0·46
26·5	11	5·07			
27·5	11	5·07	Total...	217	99·95

Age-Groups, 1909, Bahama Bank

	February.									
	♂					♀				
	1	2	3	4	5	1	2	3	4	5
20·5	1	1								
21·5		1								
22·5		1								
23·5			1							
24·5		1	2					1		
25·5		4								
26·5			2							
27·5		2	1	1						
28·5			1							
29·5		1	1	1						
30·5			1	1						
31·5		1		1				1		
32·5								1		
33·5			1	1	1					
34·5										
35·5				1						
36·5										
37·5										
38·5			1							
39·5									1	
40·5									1	
41·5										
Total...	1	12	11	6	1	...	...	3	2	...

Age-Groups, 1909, Firth of Clyde, near Corsewall Point

	June.													
	♂							♀						
	3	4	5	6	7	8	9	3	4	5	6	7	8	9
20·5														
21·5														
22·5		1												
23·5		1												
24·5									1					
25·5		1	1					1						
26·5			1					1						
27·5		2	2											
28·5			1		1					2				
29·5			1						2	1	2			
30·5							1	1		1				
31·5									1	3	1			
32·5											1	1		
33·5			1							1				
Total...	...	5	7	...	1	...	1	3	4	8	4	1	...	...

Age-Groups, Barrow Channel, 1909

Mean Length.	January.						February.						March.					
	♂			♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14·5	......	......	......	......	......	......	1	......	......	......	......	......	1	......	......	1	......	......
15·5	2	......	......	......	......	......	3	......	......	......	......	......	3	......	......	6	......	......
16·5	7	1	......	9	......	......	2	......	......	3	......	......	10	......	......	10	2	......
17·5	11	......	......	5	2	......	5	......	......	5	......	......	10	2	......	6	......	......
18·5	9	1	......	5	1	......	20	1	......	19	1	......	5	1	......	5	3	......
19·5	6	2	......	4	......	......	4	......	......	4	1	......	1	......	......	2	1	......
20·5	......	1	......	1	2	......	4	1	......	2	3	......	2	1	......	......	1	......
21·5	......	2	......	1	......	......	1	5	......	......	2	......	1	1	......	......	......	......
22·5	......	......	......	2	1	......	......	5	......	......	......	......	......	1	......	......	1	......
23·5	......	1	......	......	3	......	......	5	......	......	5	......	......	1	......	......	1	......
24·5	......	......	......	1	1	......	......	4	......	......	1	......	......	......	......	......	......	......
25·5	......	......	......	......	1	......	......	1	......	......	1	......	......	......	......	......	......	......
26·5	......	2	......	......	......	......	......	......	......	......	1	......	......	......	......	......	......	......
27·5	......	2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
28·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
29·5	......	......	......	......	......	(4)	......	......	......	......	......	......	......	......	......	......	......	......
30·5	......	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......
Total...	35	12	...	28	11	1	40	22	...	33	15	...	33	7	...	30	9	...

Mean Length.	April.						May.						June.					
	♂			♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13 5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14·5	......	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	......	......
15·5	......	......	......	......	......	......	5	......	......	2	......	......	1	......	......	1	......	......
16·5	1	......	......	1	......	......	7	......	......	9	......	......	2	......	......	3	......	......
17·5	2	5	......	......	3	......	4	......	......	9	4	......	......	3	......	......	5	......
18·5	1	2	......	......	4	......	9	2	......	3	......	......	......	6	......	1	9	......
19·5	......	1	......	......	2	......	3	1	......	10	1	......	......	8	......	......	5	......
20·5	......	1	1	......	2	1	3	2	......	3	......	......	......	6	......	......	10	......
21·5	......	......	......	......	......	......	2	2	......	2	......	......	......	5	......	......	4	......
22·5	......	......	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	......
23·5	......	......	......	......	......	......	......	......	......	1	2	......	......	......	......	......	2	......
24·5	......	......	......	......	......	......	......	......	......	1	1	......	......	......	......	......	......	......
25·5	......	......	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	......
26·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1	......
Total...	4	9	1	1	11	1	33	7	......	40	8	......	4	30	......	5	36	......

Age Groups, Barrow Channel.

Mean Length.	July.						October.					
	♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......
12·0	......	......	......	......	......	......	......	......	......	......	......	......
13·5	......	......	......	......	......	......	......	......	......	......	......	......
14·5	......	......	......	......	......	......	......	......	......	......	......	......
15·5	3	......	......	......	......	......	......	......	......	1	......	......
16·5	2	......	......	3	......	......	1	1	......	4	......	......
17·5	......	1	......	1	6	......	8	......	......	8	......	......
18·5	2	4	......	......	2	......	13	1	......	7	......	......
19·5	......	7	......	......	5	......	9	1	......	4	3	......
20·5	......	4	......	......	2	......	......	6	......	6	4	1
21·5	......	10	......	......	6	......	1	5	......	3	4	......
22·5	......	8	......	......	6	......	......	5	......	......	6	......
23·5	......	6	1	......	3	......	1	7	......	1	2	1
24·5	......	1	1	......	3	1	......	3	......	......	8	......
25·5	......	2	2	......	2	......	......	3	......	......	5	1
26·5	......	......	......	......	......	......	......	4	......	......	4	......
27·5	......	1	......	......	1	1	......	5	......	......	2	......
28·5	......	......	......	......	......	......	......	2	......	......	1	1
29·5	......	......	......	......	......	......	......	2	......	......	2	......
30·5	......	......	......	......	......	......	......	......	2	......	1	......
31·5	......	......	......	......	......	......	......	......	......	......	......	......
32·5	......	......	......	......	......	......	......	2	1	......	1	......
Total...	7	44	4	4	36	2	33	47	3	34	43	4

Duddon Banks, 1909. Near Nelson Buoy, 1909

Mean Length.	March.						June.					
	♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......
12·5	......	......	......	......	......	......	......	......	......	......	......	......
13·5	......	......	......	......	......	......	......	......	......	......	......	......
14·5	3	......	......	......	......	......	......	......	......	1	......	......
15·5	5	......	......	4	......	......	4	1	......	3	2	......
16·5	5	......	......	6	4	......	3	3	......	1	6	......
17·5	8	18	......	5	12	......	1	8	......	1	10	3
18·5	10	12	1	4	15	1	......	21	2	2	11	1
19·5	2	5	2	1	2	1	......	33	3	......	23	......
20·5	......	2	1	......	1	2	......	11	1	......	15	3
21·5	......	2	......	......	1	......	......	7	3	......	22	3
22·5	......	......	......	......	......	......	......	10	2	......	5	......
23·5	......	1	......	......	......	......	......	1	......	......	4	4
24·5	......	......	......	......	......	1	......	......	1	......	......	1
25·5	......	......	......	......	......	......	......	......	......	......	1	......
26·5	......	......	......	......	......	......	......	......	......	......	......	1
Total...	33	40	4	20	35	5	8	95	12	8	99	16

Age-Groups, Rock Channel, 1909

Mean Length.	February.						May.						June.					
	♂			♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12·5	1	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	......	......
13·5	......	......	......	2	......	......	1	......	......	......	......	......	1	......	......	......	......	......
14·5	5	......	......	2	......	......	1	......	......	......	......	......	5	3	......	9	......	......
15·5	6	......	......	4	1	......	3	1	......	......	1	......	13	3	......	7	9	......
16·5	14	......	......	18	1	......	2	......	......	2	1	......	6	11	......	8	7	1
17·5	10	......	......	15	......	......	......	......	......	3	1	......	1	19	......	8	5	1
18·5	9	1	......	10	1	......	4	......	......	7	1	......	2	17	......	5	14	......
19·5	3	2	......	8	2	......	3	7	......	1	8	......	......	15	......	......	17	......
20·5	1	4	......	2	2	......	......	6	......	......	5	......	......	12	......	......	6	1
21·5	1	3	......	1	3	......	......	1	......	......	1	1	......	6	......	......	6	1
22·5	......	2	......	1	2	......	......	......	......	......	1	......	......	......	......	......	4	1
23·5	......	......	......	......	1	......	......	1	......	......	......	......	......	......	2	......	1	3
24·5	......	......	......	......	2	......	......	......	......	......	......	......	......	......	1	......	......	......
25·5	......	......	1	......	1	......	......	......	......	......	......	......	......	......	......	......	......	......
26·5	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......	......
27·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
28·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
29·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
30·5	......	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......
Total...	50	12	1	63	17	1	14	16	...	13	19	1	29	86	3	37	69	8

Mean Length.	July.						October.						November.					
	♂			♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14·5	4	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......	......	......
15·5	5	1	......	7	......	......	1	......	......	2	......	......	......	......	......	......	......	......
16·5	11	......	......	15	1	......	3	......	......	6	......	......	......	......	......	1	1	......
17·5	6	1	......	7	......	......	11	......	......	5	......	......	2	2	......	1	1	......
18·5	7	2	......	4	1	......	6	......	......	14	......	......	3	1	......	4	2	......
19·5	4	1	......	......	......	......	11	......	......	6	......	......	2	3	......	1	8	......
20·5	......	......	......	......	......	......	8	......	......	7	2	......	1	5	......	1	6	......
21·5	......	......	......	......	1	......	3	......	......	1	1	......	......	9	......	......	7	......
22·5	......	......	......	......	......	......	2	......	......	7	2	......	......	1	......	......	1	......
23·5	......	......	......	......	......	......	3	......	......	1	1	......	......	1	......	......	......	......
24·5	......	......	......	......	......	......	......	1	......	......	1	......	......	......	......	......	1	......
25·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
26·5	......	......	......	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......
27·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
28·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
29·5	......	......	......	......	......	......	......	......	......	......	1	......	......	......	......	......	......	......
Total...	37	5	...	34	3	...	48	2	...	49	8	...	8	22	...	8	27	.....

Age-Groups, Fleetwood Channel, 1909

Mean Length.	February.						March.						September.					
	♂			♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5																		
11·5																		
12·5																		
13·5										1								
14·5				2						2								
15·5	3			5			3			4			2			2		
16·5	2	2		2	1		5	3		10	1		1				1	
17·5	3	3		4			4	5		9	5		4			4		
18·5					1		2	8		5	7		4	1			3	
19·5		1		1	1		2	4			5			1		2	5	
20·5				1	1			6	1	1	9		1	4		1	2	
21·5		1			1			4		1	7						4	
22·5					3			5			1			5	1		5	
23·5					2			3			7	1		5			5	
24·5		1						2						8				2
25·5					2			2			1			4	1		1	2
26·5											1			2	1		3	2
27·5														3	2			1
28·5																	1	
29·5																		
30·5					1													1
31·5																		
32·5																		
33·5																		
34·5																		
35·5																		
36·5																		
37·5																		
38·5																		
39·5																		
Total...	8	8	...	15	13	...	16	42	1	33	44	1	12	33	5	9	30	8

Age-Groups, Beaumaris Bay and Red Wharf Bay

Mean Length.	July.								September.							
	♂				♀				♂				♀			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
15·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
16·5	5	3	......	......	2	3	......	......	3	2	......	......	2	1	......	......
17·5	4	10	......	......	2	15	......	......	1	1	......	......	3	2	......	......
18·5	4	13	......	......	1	15	......	......	2	6	......	......	2	4	......	......
19·5	......	15	......	......	......	2	......	......	1	3	......	......	......	4	......	......
20·5	......	6	......	......	......	13	......	......	1	3	......	......	......	4	......	......
21·5	......	12	1	......	......	6	......	......	......	1	......	......	......	2	1	......
22·5	......	4	1	......	......	9	......	......	......	2	......	......	......	4	......	......
23·5	......	4	1	......	......	7	1	......	......	2	......	......	......	4	1	......
24·5	......	3	1	......	......	3	2	......	......	1	......	......	......	1	......	......
25·5	......	1	2	......	......	1	1	......	......	1	1	......	......	1	......	......
26·5	......	......	......	......	......	......	......	......	......	......	......	......	......	2	......	......
27·5	......	......	......	......	......	......	......	......	......	......	......	......	......	5	......	......
28·5	......	......	......	......	......	......	1	......	......	3	1	......	......	1	2	......
29·5	......	......	......	......	......	......	1	......	......	1	......	......	......	......	......	......
30·5	......	......	1	......	......	......	......	2	......	......	......	......	......	1	2	......
31·5	......	......	......	......	......	......	......	......	......	......	1	......	......	......	1	......
32·5	......	......	......	......	......	......	1	......	......	......	1	......	......	......	2	......
33·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
34·5	......	......	......	1	......	......	......	1	......	......	......	1	......	......	1	......
35·5	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	1
36·5	......	......	......	1	......	......	......	1	......	......	......	......	......	......	......	1
37·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
38·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
39·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
40·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
41·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
42·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1
43·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
44·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Total...	13	71	7	3	5	74	7	4	8	26	4	1	7	36	10	3

Age-Groups, Beaumaris Bay and Red Wharf Bay—*Continued*

Mean Length.	November.								December. (Red Wharf Bay.)								
	♂				♀				♂				♀				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5
15·5	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......	......	......
16·5	1	......	......	......	2	......	......	......	2	......	......	......	......	1	......	......	......
17·5	2	1	......	......	2	1	......	......	1	3	......	......	1	......	......	......	......
18·5	......	......	......	......	2	......	......	......	2	1	......	......	1	1	......	......	......
19·5	......	2	......	......	......	......	......	......	......	2	......	......	......	2	......	......	......
20·5	2	1	......	......	2	......	......	......	1	1	......	......	......	3	......	......	......
21·5	......	1	......	......	......	3	......	......	1	3	......	......	......	4	......	......	......
22·5	......	......	......	......	......	1	......	......	......	2	......	......	......	......	......	......	......
23·5	......	......	......	......	......	6	......	......	......	3	......	......	......	1	1	......	......
24·5	......	2	......	......	......	1	......	......	......	1	1	......	......	2	......	......	......
25·5	......	......	......	......	......	2	1	......	......	......	1	......	......	1	2	......	......
26·5	......	1	1	......	......	1	......	......	......	......	1	......	......	3	3	......	......
27·5	......	......	1	......	......	2	3	......	......	4	......	......	......	1	4	......	......
28·5	......	......	......	......	......	......	......	......	......	1	1	......	......	4	3	......	......
29·5	......	......	......	......	......	1	1	......	......	......	......	......	......	......	3	1	......
30·5	......	......	......	......	......	......	......	......	......	......	2	......	......	......	1	......	......
31·5	......	......	......	......	......	1	......	......	......	......	......	1	......	......	1	......	......
32·5	......	......	......	......	......	......	......	......	......	......	2	......	......	......	4	......	......
33·5	......	......	......	......	......	......	1	......	......	......	......	......	......	......	......	......	......
34·5	......	......	......	......	......	......	......	......	......	......	......	1	......	......	1	2	......
35·5	......	......	......	......	......	......	......	1	......	......	1	......	......	......	......	1	......
36·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
37·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
38·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
39·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
40·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
41·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1	1
42·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1
43·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1
44·5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Total...	5	8	2	...	9	19	6	1	7	21	9	2	2	23	23	5	3

Modal Lengths in Centimetres of Plaice captured by a 6″ trawl-mesh, 1909

Locality.	Duddon Banks.	Barrow Channel.	Fleetwood Channel.	Nr. Nelson Buoy.	Horse Channel.	Rock Channel.	Nr. Mersey Bar	Beaumaris Bay.	Red Wharf Bay.	Near New Quay Head.
Jan.	—	17·6 (23·5) (26·8)	—	—	—	—	—	—	—	—
Feb.	—	17·7 (22)	17·2 (23·2)	—	—	—	—	—	—	29·3
Mar.	18·4	17·8	18·4	16·8 (22·6)	—	16·6	—	—	—	26·6 (37·4)
April	19·4	17·6	—	—	—	17·4	—	—	—	24·2 (30·9)
May	19·7	18·5	—	21·6	—	17·9	—	—	—	20·75 (27·1)
June	—	20·3	19·5	19·9	18·3	16·6 (21·0)	19·5	20·7	19·2	—
July	—	24·8	21·6	21·3	20·8	17·2	20·8	20·0	20·7	—
Aug.	—	24·2	22·0	18·2	19·3	—	—	—	22·5	—
Sept.	—	—	22·2	17·8	21·5	19·1	17·9	18·9 (27·6)	—	—
Oct.	—	19·8 (18·9) (28·1)	19·0	—	20·0	18·0	—	18·4 (26·0)	19·2 (25·4)	—
Nov.	19·5 (27·8)	—	—	—	20·0	—	—	18·1 (26·1)	23·0	—
Dec.	—	18·6	—	—	—	—	—	24·8 (31·6)	18·2 (26·8)	—

Values of the Length-Weight Coefficient k, 1909

$$\frac{\Sigma\ g}{\Sigma\ l^3}$$

Locality.	Duddon Banks	Barrow Channel	Fleetwood Channel.	Nr. Nelson Buoy.	Near Rock Channel.	Beaumaris* Bay.	Menai Straits.	Carnarvon Bay.
January	—	0·923	0·865	—	0·866	—	—	—
February	—	0·987 0·931	1·00	—	0·765 0·912	—	0·973	—
March	0·924	0·968	0·897	—	0·884	—	0·672 1·00	—
April	1·09	0·981	—	—	0·917	—	—	—
May	—	1·00	—	—	1·02	—	—	0·977
June	—	1·16	—	0·943	1·00 1·10 0·949	1·06 1·09 —	—	—
July	—	1·16	—	—	1·03 1·16	—	—	—
August	—	1·20†	—	—	1·03 1·08	—	—	—
September	—	1·07†	—	—	0·966	1·06	—	—
October	—	1·00	—	—	1·01	—	—	—
November	—	—	—	—	1·03	1·06 1·05	—	—
December	—	—	—	—	—	1·01 0·965	—	—

* Includes Red Wharf Bay. † Interpolated values.

Modal Lengths of Plaice of Age-Groups I and II, 1909.

Locality	Barrow Channel.				Duddon Banks.				Near Nelson Buoy.			
Sex	♂		♀		♂		♀		♂		♀	
Age-Group	1	2	1	2	1	2	1	2	1	2	1	2
Jan. ...	17·8	—	17·6	—	—	—	—	—	—	—	—	—
Feb. ...	19	23·1	18·9	22·6	—	—	—	—	—	—	—	—
March ...	17·5	—	17·1	—	18·4	18·3	17·6	18·2	—	—	—	—
April ...	—	—	—	—	—	—	—	—	—	—	—	—
May ...	18	—	18·75	—	—	—	—	—	—	—	—	—
June ...	—	20·2	—	20·2	—	—	—	—	16·5	19·8	16·25	20·3
July ...	—	22	—	22	—	—	—	—	—	—	—	—
Aug. ...	—	—	—	—	—	—	—	—	—	—	—	—
Sept. ...	—	—	—	—	—	—	—	—	—	—	—	—
Oct. ...	18·7	21·9	18·9	22·6	—	—	—	—	—	—	—	—
Nov. ...	—	—	—	—	—	—	—	—	—	—	—	—
Dec. ...	—	—	—	—	—	—	—	—	—	—	—	—
	Rock Channel.				Beaumaris Bay.				Fleetwood Channel.			
Jan. ...	—	—	—	—	—	—	—	—	—	—	—	—
Feb. ...	17·6	21·2	18·2	21·5	—	—	—	—	16·3	17·5	16·5	22·5
March ...	—	—	—	—	—	—	—	—	17·4	19·8	17·3	20·3
April ...	—	—	—	—	—	—	—	—	—	—	—	—
May ...	17·0	20·8	18·5	20·7	—	—	—	—	—	—	—	—
June ...	16·1	19·5	16·4	19·5	—	—	—	—	—	—	—	—
July ...	17·0	—	17·2	—	—	19·5	—	19·75	—	—	—	—
Aug. ...	—	—	—	—	—	—	—	—	—	—	—	—
Sept. ...	—	—	—	—	—	19·6	—	20·9	18	24·7	18·5	21·75
Oct. ...	19·1	—	19·1	—	—	—	—	—	—	—	—	—
Nov. ...	—	22·2	—	21·2	—	24·2	—	24·2	—	—	—	—
Dec. ...	—	—	—	—	—	22·5	—	22·5	—	—	—	—

Plaice, Age-Group II, Male. Catch of 44 from Barrow Channel, 12 July, 1909.

Mean length in cents.	Frequency (observed).	Frequency (smoothed).	Deviation from mode. σ	Theoretical frequency.
17·5	1	1	1·72	1·7
18·5	4	4	1·29	3·29
19·5	7	5	0·86	5·23
20·5	4	7	0·43	6·9
21·5	10	7·3	—	7·58
22·5	8	8	0·43	6·9
23·5	6	5	0·86	5·23
24·5	1	3	1·29	3·29
25·5	2	1	1·72	1·7
26·5	—	1	2·15	0·65
27·5	1	1	2·58	0·26

Standard deviation $= \sigma = 2{\cdot}32$.

Mode $= 21{\cdot}9$ (taken as $21{\cdot}5$).

Σ errors$^2 = 238{\cdot}1$.

Maximum ordinate $\dfrac{n}{\sigma\sqrt{2\pi}} = 7{\cdot}58$.

Length-Frequencies, Group II, Males; Nelson Buoy, June 1909. Comparison with Normal Curve of Error.

Mean length in cents.	Frequency.	Smoothed frequency.	Deviation from mode. σ	Theoretical frequency.
15·5	1	1	2·4	1·26
16·5	3	4	1·8	4·48
17·5	8	10·7	1·2	11·01
18·5	21	20·7	0·62	18·69
19·5	33	21·7	—	22·66
20·5	11	17	0·62	18·69
21·5	7	9·3	1·2	11·01
22·5	10	6	1·8	4·48
23·5	1	1	2·4	1·26

No. of observations $= n = 91{\cdot}4$.

Arithmetic average $= 19{\cdot}52$.

Empirical mode $= 19{\cdot}5$.

Standard deviation $= \sqrt{\dfrac{\Sigma\,\delta^2}{n}} = \sigma = 1{\cdot}61$.

Sum of errors squared, $\Sigma\,\delta^2 = 238{\cdot}5$.

Maximum frequency $= \dfrac{n}{\sigma\sqrt{2\pi}} = 22{\cdot}66$.

Length-Frequencies, Group II, Females; Nelson Buoy, June 1909. Comparison with Normal Curve of Error.

Mean length in cents.	Frequency.	Smoothed frequency.	Deviation from mode. σ	Theoretical frequency.
15·5	2	2	2·4	1·08
16·5	6	6	1·9	3·17
17·5	10	9	1·4	7·26
18·5	11	14·7	0·99	11·85
19·5	23	16·3	0·5	17·08
20·5	15	20	—	19·37
21·5	22	14	0·5	17·08
22·5	5	10·3	0·99	11·85
23·5	4	3	1·4	7·26
24·5	—	1·7	1·9	3·17
25·5	1	1	2·4	1·08

n = no. of observations = 98.

Arithmetic average = 20·03.

Empirical mode = 20·5.

$\Sigma\ \delta^2$ = Sum of errors squared = 409·88.

Standard deviation, σ, $= \sqrt{\dfrac{\Sigma\ \delta^2}{n}} = 2{\cdot}019.$

Maximum frequency $= \dfrac{n}{\sigma \sqrt{2\pi}} = 19{\cdot}37.$

Measurements of 200 Plaice hatched at Port Erin on 26 April, 1906, and examined on 27 May, 1907.

Limits of Length in inches.	Distance from mode in inches. x'	Actual Nos. between limits. f	$\frac{x'}{c}$	$f(x)$		$f(x) \times N$ (calculated Nos.)
1¼ to 1½	−1·375 to 1·125	2	−1·72	0·493	0·017	3·12
1½ „ 1¾	−1·125 „ 0·875	1	−1·4	0·476	0·038	6·9
1¾ „ 2	−1·875 „ 0·625	20	−1·09	0·438	0·076	13·9
2 „ 2¼	−0·625 „ 0·375	26	−0·77	0·362	0·115	21·16
2¼ „ 2½	−0·375 „ 0·125	29	−0·47	0·247	0·157	28·8
2½ „ 2¾	−0·125 „ +0·125	37	−0·16 +0·16	0·090 0·090	0·180	33·1
2¾ „ 3	+0·125 „ 0·375	25	+0·47	0·247	0·157	28·8
3 „ 3¼	+0·375 „ 0·625	24	+0·77	0·362	0·115	21·16
3¼ „ 3½	+0·625 „ 0·875	12	+1·09	0·438	0·076	13·9
3½ „ 3¾	+0·875 „ 1·125	4	+1·4	0·476	0·038	6·9
3¾ „ 4	+1·125 „ 1·375	4	+1·72	0·493	0·017	3·12
4 „ 4¼	—	8				
4¼ „ 4½	—	5				
4½ „ 4¾	—	1				
4¾ „ 5	—	—				
5 „ 5¼	—	—				
5¼ „ 5½	—	1				
5½ „ 5¾	—	1				

$N = 184$ (the part of the series above 3¾ to 4 being neglected).

Standard deviation =

$$\sigma = \sqrt{\frac{\Sigma(x'^2 f)}{N}} = 0{\cdot}505.$$

Modulus $= c = \sqrt{2}.\sigma = 0{\cdot}712$.

Mode is at 2·625 inches.

$f(x)$ is $\dfrac{1}{\sqrt{\pi}}\displaystyle\int_0^x e^{-x^2}.dx$, the equation for the integral curve of error. Values are tabulated in Bowley's *Elements of Statistics*, ed. 2, 1902, p. 281.

$f(x) \times N$ are the nos. of fish on the algebraic curve occurring between the limits in Column I.

Partial Catches Measured Twice.

A : On board S.S. " James Fletcher " when alive.

B : At Liverpool Laboratory about 24 hours later.

Nos. at and above each centimetre in length.

	Conway Bay 27.11.09		Conway Bay 17.11.09		Conway Bay 22.9.09		Conway Bay 23.7.09	
	A	B	A	B	A	B	A	B
14·5					101	101	202	202
15·5	51	51	51	51	99	99	201	200
16·5	50	49		49	98	97	192	194
17·5	47	44	48	46	89	89	183	181
18·5	43	42	44	40	80	82	148	150
19·5	42	41	39	38	68	68	120	117
20·5	40	38	36	36	59	60	92	91
21·5	38	36	32	31	52	52	71	72
22·5	36	33	29	27	49	48	49	53
23·5	32	32	26	26	40	42	37	38
24·5	31	30	23	20	35	35	24	25
25·5	26	23	19	17	33	33	16	16
26·5	21	17	16	14	28	30	13	13
27·5	16	14	14	11	27	28		
28·5	13	11	10		23	23	11	11
29·5	11	7	5	5	16	16	10	10
30·5	7	5			15	15	9	9
31·5			3	3	11	11	6	
32·5	3	3			8	8		6
33·5	2		2	2	4	5	5	5
34·5					3	4		
35·5				1	2	3	3	3
36·5			1			2	2	2
37·5						1		
38·5								
39·5	1	1						
40·5					1			
Total	51	51	51	51	101	101	202	202

THE HYDROGRAPHIC WORK IN THE IRISH SEA DURING 1909: A POSSIBLE BEARING ON METEOROLOGICAL WORK.

By Henry Bassett, Jun., D.Sc., Ph.D., Assistant Lecturer in Chemistry in the University of Liverpool.

The hydrographic work carried out by us in the Irish Sea during 1909 has followed the lines indicated at the end of last year's report.* Quarterly observations at the 15 stations indicated on the chart (p. 186) have been made, while additional observations at stations 1 to 7 were made half-way between the quarterly cruises, the samples, as usual, having been collected by my colleague, Mr. J. Johnstone, B.Sc.

In the tables which follow, T°, Cl °/₀₀, S °/₀₀, and σ_t have the usual meanings.

A discussion of the results, which seem to be of unusual interest, is given after the tables.

Jan. 25 to 29, 1909.

Station I. 25/1/09 (2.25 p.m.). 54° N.; 3° 30′ W. Depth of station, 29·3 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·2	18·03	32·57	25·75
25	5·2	18·03	32·57	25·57

Station II. 25/1/09 (3.25 p.m.). 54° N.; 3° 47′ W.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·8	18·29	33·04	26·06

* Trans. Biol. Soc. of Liverpool, Vol. XXIII., p. 146 (1909); also Lancashire Sea Fisheries Laboratory Report, No. 17, p. 44 (1909).

Fig. 21. Hydrographic Stations during 1909.

Station III. 25/1/09 (4.25 p.m.). 54° N.; 4° 4′ W.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	6·4	18·52	33·46	26·30

Station IV. 25/1/09 (5.10 p.m.). 54° N.; 4° 20′ W. Depth of station, 47·6 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	7·7	18·73	33·84	26·43
45	7·6	18·72	33·82	26·44

Station V. 27/1/09 (11.30 a.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 100·7 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	8·3	18·74	33·86	26·35
50	8·15	—	—	—
100	8·2	18·74	33·86	26·36

The samples for Station V were actually collected from a point about one mile W. of the correct position (given above).

Station VI. 27/1/09 (10.25 a.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 60·4 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	8·4	18·78	33·93	26·39
25	8·3	—	—	—
58	8·3	18·77	33·91	26·39

Station VII. 27/1/09 (9.25 a.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 53·1 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	8·15	18·81	33·98	26·48
25	8·1	—	—	—
50	8·1	18·79	33·95	26·46

Station VIII. 26/1/09 (12.20 p.m.). 54° 4′ N.; 3° 28′ W. Depth of station, 29·3 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·3	18·05	32·61	25·77
25	5·2	18·05	32·61	25·78

Only surface observations were taken at the following stations:—

Station.	Date and Time.	T°	Cl °/₀₀	S °/₀₀	σ_t
IX. 54° 9′ N.; 3° 44′ W.	26.1.09 (11.30 a.m.)	5·9	18·46	33·35	26·29
X. 54° 12′ N.; 4° W.	26.1.09 (10.40 a.m.)	6·0	18·55	33·51	26·41
XI. 53° 54′ N.; 3° 59′ W.	29.1.09 (9.45 a.m.)	6·8	18·71	33·80	26·52
XII. 53° 47′ N.; 3° 45′ W.	29.1.09 (10.45 a.m.)	6·1	18·51	33·44	26·33

Station XIII. 29/1/09 (11.45 a.m.). 53° 39′ N.; 3° 30′ W. Depth of station, 29·3 metres.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	5·65	18·33	33·12	26·13
26	5·5	18·33	33·12	26·14

Station XIV. 26/1/09 (5.30 p.m.). 53° 30′ N.; 4° 1′ W.

Depth (metres)	T°	Cl °/₀₀	S °/₀₀	σ_t
0	7·5	18·83	34·02	26·60

March 19 to 21, 1909.

Station I. 19/3/09 (11.10 a.m.). 54° N.; 3° 30′ W. Depth of station, 25·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	4·95	18·32	33·10	26·19
24	4·7	—	—	—

Station II. 19/3/09 (12 noon). 54° N.; 3° 47′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	5·5	18·48	33·39	26·38
40	5·2	—	—	—

Station III. 19/3/09 (1 p.m.). 54° N.; 4° 4′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	5·85	18·64	33·68	26·56
40	5·65	—	—	—

Station IV. 19/3/09 (2 p.m.). 54° N.; 4° 20′ W. Depth of station, 49 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	5·75	18·65	33·69	26·57
47	5·5	—	—	—

Station V. 19/3/09 (3.50 p.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 65·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	6·6	18·78	33·93	26·65
35	6·5	—	—	—
63	6·55	18·78	33·93	26·65

Station VI. 19/3/09 (4.55 p.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 54·9 metres.

Depth (metres)	T°	C, ‰	S ‰	σ_t
0	6·7	18·81	33·98	26·68
25	6·47	—	—	—
52	6·45	18·81	33·98	26·71

Station VII. 19/3/09 (5.50 p.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 56·7 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	6·3	18·81	33·98	26·74
25	6·15	—	—	—
55	6·15	18·82	34·00	26·76

Temperature observations alone were made at stations VIII to XIV.

For the rest of the year the line of soundings Nos. XI to XIV was slightly altered so as to run from the Calf of Man to the Liverpool North West Lightship.

May 17 to 19, 1909.

Station I. 17/5/09 (11.30 a.m.). 54° N.; 3° 30′ W. Depth of station, 27·4 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	10·35	18·16	32·81	25·21
25	8·85	18·17	32·83	25·47

Station II. 17/5/09 (12.30 p.m.). 54° N.; 3° 47′ W. Depth of station, 38·5 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·05	18·34	33·13	25·52
35	8·35	—	—	—

Station III. 17/5/09 (1.25 p.m.). 54° N.; 4° 4′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·9	18·65	33·69	26·13
38	8·55	—	—	—

Station IV. 17/5/09 (2.25 p.m.). 54° N.; 4° 20′ W. Depth of station, 51·2 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·9	18·85	34·05	26·41
49	8·65	18·86	34·07	26·48

Station V. 18/5/09 (8.25 a.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 100·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·53	18·93	34·20	26·59
10	8·42	—	—	—
50	8·42	—	—	—
100	8·42	18·93	34·20	26·61

Station VI. 18/5/09 (9.30 a.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 63·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	8·5	18·94	34·22	26·60
10	8·3	—	—	—
30	8·3	—	—	—
63	8·3	18·94	34·22	26·63

Station VII. 18/5/09 (10.25 a.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 82·4 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	8·7	18·90	34·14	26·52
10	8·6	—	—	—
30	8·6	—	—	—
80	8·45	18·90	34·14	26·56

Only surface observations were taken at the following stations:—

Station.	Date and Time.	T°	Cl ‰	S ‰	σ_t
VIII. 54° 4′ N.; 3° 28′ W.	19.5.09 (10.50 a.m.)	9·3	18·29	33·04	25·56
IX. 54° 9′ N.; 3° 44′ W.	19.5.09 (9.55 a.m.)	9.05	18·30	33·06	25·62
X. 54° 12′ N.; 4° W.	19.5.09 (8.55 a.m.)	8.95	18.31	33·08	25·64

Station XI. 18/5/09 (6.45 p.m.). 53° 56′ N.; 4° 31′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	8·80	18·87	34·09	26·46
55	8·75	—	—	—

Station XII. 18/5/09 (5.30 p.m.). 53° 48′ N.; 4° 11′ W. Depth of station, 47·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	8·83	18·77	33·91	26·31
43	8·65	—	—	—

Station XIII. 18/5/09 (4.25 p.m.). 53° 41′ N.; 3° 51′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·1	18·48	33·39	25·87
40	8·7	—	—	—

Station XIV. 18/5/09 (3.10 p.m.). 53° 31′ N.; 3° 31′ W. Depth of station, 31·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·5	18·19	32·86	25·39
30	9·1	18·22	32·92	25·50

Station XV. 18/5/09 (1.10 p.m.). 53° 26′ N.; 4° 6′ W.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·3	18·57	33·55	25·96

June 14 to 18, 1909.

Station I. 14/6/09 (1 p.m.). 54° N.; 3° 30′ W. Depth of station, 27·5 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·4	18·27	33·01	24·99
24	10·7	—	—	—

Station II. 14/6/09 (2 p.m.). 54° N.; 3° 47′ W. Depth of station, 38·4 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·5	18·41	33·26	25·16
35	10·65	—	—	—

Station III. 14/6/09 (3 p.m.). 54° N.; 4° 4′ W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·33	18·30	33·06	24·85
40	10·5	—	—	—

Station IV. 14/6/09 (4 p.m.). 54° N.; 4° 20′ W. Depth of station, 49·4 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·73	18·85	34·05	25·92
46	10·65	—	—	—

Station V. 14/6/09 (5.40 p.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 69·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	10·62	18·90	34·14	26·20
30	10·00	—	—	—
65	10·00	18·89	34·13	26·29

Station VI. 14/6/09 (6.50 p.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 69·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	10·1	18·95	34·23	26·36
30	9·85	—	—	—
65	9·8	18·95	34·23	26·41

Station VII. 14/6/09 (7.55 p.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 65·9 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	10·42	18·95	34·23	26·29
30	10·25	—	—	—
62	10·25	18·94	34·22	26·31

Two sets of observations were made on the June trip in the deep water off the Mull of Galloway.

54° 34′ 30″ N.; 5° W. 16/6/09 (10.40-11 a.m.). Depth of station, 256·2 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·45	18·78	33·93	26·22
50	9·10	18·79	33·95	26·30
100	8·87	18·81	33·98	26·36
220	8·75	18·81	33·98	26·39

54° 50′ N.; 5° 19′ W. 16/6/09 (1.45-2 p.m.). Depth of station, 245·2 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	9·35	18·79	33·95	26·26
50	8·61	18·79	33·95	26·38
100	8·55	18·79	33·95	26·39
230	8·51	18·79	33·95	26·40

July 26 to 28, 1909.

Station I. 26/7/09 (2 p.m.). 54° N.; 3° 30′ W. Depth of station, 23·8 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	14·73	18·19	32·86	24·40
23	14·60	18·19	32·86	24·43

Station II. 26/7/09 (3 p.m.). 54° N.; 3° 47′ W. Depth of station, 34·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·87	18·52	33·46	25·03
30	13·6	—	—	—

Station III. 26/7/09 (4 p.m.). 54° N.; 4° 4′ W. Depth of station, 45·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·65	18·58	33·57	25·16
40	13·15	—	—	—

Station IV. 26/7/09 (5 p.m.). 54° N.; 4° 20′ W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·95	18·78	33·93	25·58
40	12·75	18·80	33·96	25·66

Station V. 27/7/09 (8 a.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 80·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·45	18·88	34·11	25·83
30	12·00	—	—	—
75	11·77	18·94	34·22	26·04

Station VI. 27/7/09 (9.15 a.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·80	18·88	34·11	25·76
30	12·45	—	—	—
55	12·45	18·90	34·14	25·86

Station VII. 27/7/09 (10.25 a.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 53·1 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	13·3	18·82	34·00	25·57
30	12·8	—	—	—
50	12·75	18·91	34·16	25·81

Only surface observations were made at stations VIII, IX and X.

Station.	Date and Time.	T°	Cl °/oo	S °/oo	σ_t
VIII. 54° 4′ N.; 3° 28′ W.	28.7.09 (8.15 a.m.)	15·15	18·10	32·70	24·18
IX. 54° 9′ N.; 3° 44′ W.	28.7.09 (7.55 a.m.)	14.15	18.41	33.26	24.83
X 54° 12′ N.; 4° W.	28.7.09 (6.30 a.m.)	13.75	18·46	33·35	24·99

Station XI. 27/7/09 (8.40 p.m.). 53° 56′ N.; 4° 31′ W. Depth of station, 67·7 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	12·5	18·87	34·09	25·81
30	12·1	—	—	—
63	12·05	18·90	34·14	25·94

Station XII. 27/7/09 (7 15 p.m.). 53° 48′ N.; 4° 11′ W. Depth of station, 51·2 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·65	18·87	34·09	25·78
48	12·4	—	—	—

Station XIII. 27/7/09 (6 p.m.). 53° 41′ N.; 3° 51′ W. Depth of station, 45·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·75	18·55	33·51	25·11
42	12·85	18·74	33·86	25·54

Station XIV. 27/7/09 (4.25 p.m.). 53° 31′ N.; 3° 31′ W. Depth of station, 31·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·0	18·39	33·22	24·84
25	13·8	18·41	33·26	24·90

Station XV. 27/7/09 (12.50 p.m.). 53° 26′ N.; 4° 6′ W.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·0	18·53	33·48	25·03

September 14 to 17, 1909.

Station I. 14/9/09 (1.20 p.m.). 54° N.; 3° 30′ W. Depth of station, 22 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·55	18·36	33·17	24·68
21	14·15	—	—	—

Station II. 14/9/09 (2.20 p.m.). 54° N.; 3° 47′ W. Depth of station, 34·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·45	18·60	33·60	25·03
34	14·0	—	—	—

Station III. 14/9/09 (3.15 p.m.). 54° N.; 4° 4′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	14·0	18·73	33·84	25·31
40	13·7	—	—	—

Station IV. 14/9/09 (4.5 p.m.). 54° N.; 4° 20′ W. Depth of station, 45·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·6	18·84	34·04	25·55
45	13·5	—	—	—

Station V. 14/9/09 (5.25 p.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·9	18·81	33·98	25·65
30	12·8	—	—	—
57	12·8	18·81	33·98	25·67

Station VI. 14/9/09 (6.20 p.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 63·5 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·08	18·85	34·05	25·66
30	12·95	—	—	—
63	12·95	18·85	34·05	25·68

Station VII. 14/9/09 (7.20 p.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 98·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	13·4	18·88	34·11	25·64
30	13·25	—	—	—
90	13·3	18·88	34·11	25·66

Only temperature observations were made at stations VIII to XV.

November 1 to 4, 1909.

Station I. 2/11/09 (4.15 p.m.). 54° N.; 3° 30′ W. Depth of station, 29·3 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·0	18·55	33·51	25·64
26	10·77	18·55	33·51	25·68

Station II. 2/11/09 (12.20 p.m.). 54° N.; 3° 47′ W. Depth of station, 42·1 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·7	18·63	33·66	25·62
39	11·5	—	—	—

Station III. 2/11/09 (11.30 a.m.). 54° N.; 4° 4′ W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	11·6	18·73	33·84	25·79
40	11·5	—	—	—

Station IV. 2/11/09 (10.25 a.m.). 54° N.; 4° 20′ W. Depth of station, 49·4 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	11·47	18·80	33·96	25·90
45	11·40	18·80	33·96	25·92

Station V. 4/11/09 (9.25 a.m.). 53° 53′ N.; 4° 46′ W. Depth of station, 80·5 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	11·57	18·72	33·82	25·78
30	11·37	—	—	—
75	11·32	18·74	33·86	25·85

Station VI. 4/11/09 (10.30 a.m.). 53° 43′ N.; 4° 44′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl °/oo	S °/oo	σ_t
0	11·8	18·79	33·95	25·83
30	11·67	—	—	—
54	11·67	18·79	33·95	25·85

Station VII. 4/11/09 (11.35 a.m.). 53° 33′ N.; 4° 41′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	12·1	18·73	33·84	25·69
30	11·95	—	—	—
54	11·95	18·72	33·82	25·70

Only surface observations were made at stations VIII, IX and X.

Station.	Date and Time.	T°	Cl ‰	S ‰	σ_t
VIII. 54° 4′ N.; 3° 28′ W.	1.11.09 (3.30 p.m.)	11·25	18·65	33·69	25·74
IX. 54° 9′ N.; 3° 44′ W.	1.11.09 (4.25 p.m.)	11·25	18·69	33·77	25·79
X. 54° 12′ N.; 4° W.	1.11.09 (5.20 p.m.)	9·95	18·31	33·08	25·48

Station XI. 3/11/09 (3.10 p.m.). 53° 56′ N.; 4° 31′ W. Depth of station, 58·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·7	18·79	33·95	25·85
54	11·6	18·80	33·96	25·88

Station XII. 3/11/09 (1.45 p.m.). 53° 48′ N.; 4° 11′ W. Depth of station, 47·6 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·8	18·73	33·84	25·74
42	11·7	—	—	—

Station XIII. 3/11/09 (12.20 p.m.). 53° 41′ N.; 3° 51′ W. Depth of station, 43·9 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	11·5	18·44	33·31	25·40
40	11·37	18·39	33·22	25·35

Station XIV. 2/11/09 (4.15 p.m.). 53° 31′ N.; 3° 31′ W. Depth of station, 34·8 metres.

Depth (metres)	T°	Cl ‰	S ‰	σ_t
0	10·9	17·95	32·43	24·82
33	10·9	18·03	32·57	24·93

The temperature observations made at stations VIII to XV during the March, June and September cruises are given in Mr. Johnstone's paper in the present report.

In order to show the seasonal variation of the salinities more clearly, the values for the surface salinities at the various stations are collected in the accompanying table.

Table illustrating the seasonal variation of the surface salinities at the various stations during 1909.

Station	Jan. 25-29 1909	March 19-21 1909	May 17-19 1909	June 14-18 1909	July 26-28 1909	Sept. 14-17 1909	Nov. 1-4 1909
I	32·57	33·10	32·81	33·01	32·86	33·17	33·51
II	33·04	33·39	33·13	33·26	33·46	33·60	33·66
III	33·46	33·68	33·69	33·06	33·57	33·84	33·84
IV	33·84	33·69	34·05	34·05	33·93	34·04	33·96
V	33·86	33·93	34·20	34·14	34·11	33·98	33·82
VI	33·93	33·98	34·22	34·23	34·11	34·05	33·95
VII	33·98	33·98	34·14	34·23	34·00	34·11	33·84
VIII	32·61	—	33·04	—	32·70	—	33·69
IX	33·35	—	33·06	—	33·26	—	33·77
X	33·51	—	33·08	—	33·35	—	33·08
XI	33·80	—	34·09	—	34·09	—	33·95
XII	33·44	—	33·91	—	34·09	—	33·84
XIII	33·12	—	33·39	—	33·51	—	33·31
XIV	34·02	—	32·86	—	33·22	—	32·43
XV	—	—	33·55	—	33·48	—	—

A comparison of the foregoing table with the corresponding ones given in the two previous reports will at once show that the hydrographic conditions prevailing in this area during 1909 were very different from those existing in 1907 and 1908, and, so far as one can tell from the incomplete data, in 1906 also.

It is more especially stations V, VI and VII which we have to consider. These are the three stations which are affected by the Gulf Stream Drift, and where, in consequence, the maximum salinity usually occurs about February. This year, however, it will be seen that the maximum occurs much later than this, namely, in May and June, which we must regard as quite abnormal. And moreover, not only is the maximum much later, but it is also less well defined, and the salinity is somewhat lower than in previous years (34·2 ‰ instead of 34·4 ‰). The salinity variations at the remaining 12 stations, where the variations are chiefly due to varying amounts of fresh water flowing in from the neighbouring coasts, are more irregular, but on the whole the maximum salinities tend to occur during the autumn. The figures for stations IV, XI and XII suggest, however, that at these stations the tendency of the Gulf Stream Drift to cause a Spring maximum of the salinities is barely counterbalanced by the effect of the fresh coastal water.

The temperatures at nearly all the 15 stations are considerably different from those found during the period 1906-1908, so far as the various stations which—with the exception of Nos. V, VI and VII—have not always been quite the same, are comparable. During the first half of 1909 the temperatures were considerably higher than in previous years, while during the latter half of the year they were a good deal lower than usual.

The natural conclusion to draw from these results is

that during 1909 the Gulf Stream Drift was much later than usual in making itself felt in the Irish Sea, and that when the Atlantic current did appear it was of lower salinity and lower temperature than usual.

The late arrival of the Atlantic current would plainly delay the Spring maximum of the salinity at all points directly under its influence. It seems to me that the later arrival of the Atlantic current of lower temperature than usual would also account for the departure of the water temperatures from the normal which has been mentioned above.

As the Atlantic current was late, the warmer water from the end of the previous year would remain in the Irish Sea much longer than usual, and the water temperatures in the early parts of the year would consequently be above the normal; when, however, this water had been swept northwards by the inflowing and colder Atlantic water, the temperatures would fall below those found in more normal years. It may be mentioned here that the results obtained by the Irish Board of Agriculture and Technical Instruction, under Mr. E. W. L. Holt, which will be referred to more fully in the next article, fully bear out our conclusions that the salinities at points in the Irish Sea affected by the Gulf Stream Drift were at a maximum in May and June of 1909.

Now we know that the weather during 1909 was most unusual, and it seems reasonable to conclude that the abnormal weather and the abnormal Gulf Stream Drift were intimately connected.

Although the rainfall over the British Isles as a whole during 1909 was exactly equal to the average in amount, it was most abnormally distributed. The amount of rain which fell in the South-west of Ireland, Wales and England, and the North-west of Scotland, was con-

siderably below the average, while the South and East of Great Britain were much wetter than usual.*

The temperatures during 1909 were also unusual, and in spite of a few warm months, the year as a whole seems to have been colder than usual.

A short discussion of the weather of each month of 1909, by F. J. Brodie, will be found in Symons's Meteorological Magazine for 1909 (Vol. 44), where rainfall tables for the various months are also given. Many features of the weather seem to agree very well with what might be expected. Thus the rainfall for January and February was a good deal below the average, while March was much colder than usual, both of which facts can be accounted for by the absence of the large body of warm Atlantic water. In the same way the extreme dryness of August and September in the South of Ireland may well be due to the fact that the Atlantic water in the neighbourhood was colder than usual. This would, of course, result in the winds blowing from the sea to the land not being so heavily charged with moisture as usual, and a smaller precipitation on the land in consequence.

It is not, of course, for one moment to be understood that these important effects on the weather are to be attributed to the hydrographic conditions prevailing in the Irish Sea. The body of water in the latter is probably far too small for variations in its condition to have more than a very slight influence on the weather, and that only at places actually on the shores of the Irish Sea itself. It seems, however, reasonable to regard the tongue of Atlantic water which flows up the Irish Sea as an index of the Gulf Stream Drift as a whole, and it is to be expected that variations in the latter will affect the weather of these Islands, and, in fact, of North-west

* See an article in "The Times" of Jan. 14th, 1910, by Dr. H. R. Mill.

Europe. We know, of course, that the immediate causes of the weather in the British Isles are to be sought in the movements of the various cyclonic and anti-cyclonic systems in the neighbourhood. These, however, are probably influenced to a very large extent by the position and nature of the Gulf Stream Drift for the time being. The Gulf Stream Drift itself is largely regulated by the general nature of the winds due to the huge cyclonic system which rests over the North Atlantic with its centre at Iceland.*

Variations and abnormalities in the Gulf Stream Drift may therefore be expected to have an influence on the weather over extended periods of time, whereas the weather over shorter periods is dependent chiefly on the smaller cyclonic and anti-cyclonic systems then prevailing. In accordance, therefore, with these considerations, I wish to put forward the hypothesis that the peculiar weather of the past year is directly traceable to the late arrival of the Gulf Stream Drift, coupled with its unusually low temperature (due probably to greater admixture with Arctic water of low salinity).

Future work must prove or disprove this hypothesis, which I have some hesitation in bringing forward owing to the scantiness of the hydrographic data available. The mere accumulation of hydrographic data is, however, of minor interest. The interest lies with the deductions which may be made from the data. This, therefore, is my excuse for pointing out a possible line of work to which attention should be paid.

If the hydrographic conditions of the Irish Sea and the Atlantic Ocean at the mouths of the Irish Sea and English Channel are studied for a number of years, it should soon be possible to see whether any connection can

* Meinardus. Meteorologische Zeitschrift XXII, 398 (1905).

be traced between the state of the Gulf Stream Drift in these parts and the weather of the British Isles. If, as seems to me probable, an affirmative answer can be given to this query, it may well prove possible to predict the *general* character of the summer and autumn of any year from hydrographic observations made during February and March of the same year at the mouth of (or even in) the Irish Sea and English Channel. In the same way observations made during the summer would perhaps give an indication of the probable nature of the succeeding winter.

W. Meinardus* in a very striking paper has shown that there is a very intimate connection between the general circulation of the air in the North Atlantic region (which forms one large barometric unit), the marine Atlantic currents, and the weather of North-west Europe. Thus he shows that a weak atmospheric circulation over the North Atlantic during August-February corresponds to (1) low water temperatures on the coast of Europe during November-April; (2) low air temperatures in Central Europe from February-April; (3) little ice off Newfoundland during the spring; (4) plenty of ice off Iceland during the spring; (5) bad wheat and rye harvests in Western Europe and North Germany. A strong atmospheric circulation over the North Atlantic during August-February corresponds to exactly the opposite.

Helland-Hansen and Nansen, in an important paper,† have shown that the character of the summer in Northern Norway (and many important things depending upon this, such as the Lofoten cod fishery, the harvest, and so on) can be predicted a year, or even two years, in advance

* Meteorologische Zeitschrift XXII, 398 (1905).

† Internationale Revue der gesamten Hydrobiologie und Hydrographie II, 337 (1909).

from the results of hydrographic observations made off the South-west coast of Norway.

In conclusion, it may be stated that the present year may perhaps furnish a test of the views expressed in the latter part of this paper. Our hydrographic observations made at stations V, VI and VII on 2/2/10 have given values for the salinities practically identical with those found on 27/1/09. I feel confident, therefore, that the Gulf Stream Drift is late again this year, and think it very probable that the weather during summer 1910 may be similar to that of summer 1909 in consequence. This seems likely if the late Drift is also colder and fresher than usual, as it was last year. Whether this is always the case with a late Drift we have not yet sufficient data to show, but from Meinardus' observations (loc. cit.) it seems probable. Of course if, when the Gulf Stream Drift does arrive, it is salter and warmer than usual, we shall almost certainly not have the same kind of summer as we had in 1909.

THE FLOW OF WATER THROUGH THE IRISH SEA.

By Henry Bassett, Jun., D.Sc., Ph.D., Assistant Lecturer in Chemistry in the University of Liverpool.

In my reports on the Hydrographic work in the Irish Sea during 1906, 1907 and 1908,* I assumed that there was a general flow of the water from South to North, without, however, discussing the point. It seems, however, high time that this important point should be fully discussed, and for two reasons. In the first place, because it is being assumed by some people that exactly the reverse is the case, and that the water flows southwards from the Irish Sea; and in the second place, because the data now available are, for the first time, sufficient to prove without a shadow of doubt that the water does actually flow from South to North. Even before any detailed hydrographic work had been done in the Irish Sea, generally known facts were sufficient to show that in all probability there was a flow of water through the area from South to North —the current passing to the East of the Isle of Man.

Thus the general set of the tides points in this direction, the tides towards the North nearly always being stronger than those towards the South.

Then again, the sand and shingle on the English and Welsh and on the Irish coasts tend to travel northwards.†

It is a well known fact that practically all wreckage

* *Trans.*, *Biol. Soc. of Liverpool*, Vol. XXII., p. 146 (1908), and Vol. XXIII., p. 146 (1909): also *Lancashire Sea-fisheries Laboratory Reports*, No. 16, p. 54 (1908), and No. 17, p. 44 (1909).

† Mr. C. D. Oliver, M.Inst.C.E., Engineer to the Dept. of Agriculture and Technical Instruction for Ireland, in reply to enquiries kindly made for me by Professor Grenville Cole, quotes numerous cases which have come under his observation and which in his opinion show that the sand on the East Coast of Ireland travels from South to North, though probably very slowly.

from the southern parts of the Irish Sea drifts northwards and is eventually washed up on the coast of Lancashire and Cumberland, that is to say, exactly where a current from South to North, and passing to the East of the Isle of Man, would be expected to take it. The same thing almost invariably happened to bottles thrown overboard by Professor Herdman.*

Bearing these facts in mind, it seems somewhat strange that anyone should assume that the flow of water through the Irish Sea was in the contrary direction, especially since, even neglecting the above-mentioned facts, it was *a priori* improbable.

It is well known ("Law of Ferrel") that owing to the circulation of water from the poles to the equator and back to the poles, coupled with the rotation of the earth about its axis, the marine currents in the Northern Hemisphere tend to flow from S.W. to N.E. in the case of warm currents, or from N.E. to S.W. in the case of cold currents.

The Gulf Stream is one of the former, and, as is well known, flows round the North of the British Isles to the Norwegian Coast. It has been known for several years that a small branch of the Gulf Stream passes through the English Channel, and it was to be expected also that some of the eastward flowing water would succeed in forcing its way through the Irish Sea.

A current flowing southwards through the Irish Sea might be one of two kinds. It might be a cold current, which, however, would be flowing in rather the wrong direction (namely, a somewhat easterly one) for a cold current. It is, however, clear that it would be impossible for such a cold current to get down the Irish Sea, for to do so it would first have to cross the Gulf Stream flowing

* *Trans., Biol. Soc. of Liverpool*, XVII., p. 154 (1903).

round the North of Ireland and Scotland. It could only do this by going under it, which would require deep water such as does not exist to the North of Ireland, for the deep channel which runs through the western parts of the Irish Sea and the North Channel does not reach further than 6° 40′ W. Any other possible southward flowing current could only be a small eddy-like branch of the Gulf Stream. Since, however, the southern opening of the Irish Sea is much wider and more conveniently situated than the northern opening, it is far more probable that a tongue of the Gulf Stream would run through the Irish Sea from South to North, and not from North to South.

The results we obtained in 1908 would be very hard to explain by means of a southward flowing current. (See the chart in the Report of the Hydrographic Work in the Irish Sea during 1908.)

Mr. D. J. Matthews,* of the Marine Biological Association, as a result of his hydrographic investigations in the English Channel, came to the conclusion that water from the Irish Sea spread southwards over the English Channel, and J. N. Nielsen† has suggested in consequence that there is an anti-cyclonic circulation of the water round Ireland.

When Matthews' evidence is examined carefully, however, it seems to point conclusively in the opposite direction. In the Second Report of the North Sea Fisheries Investigation Committee, Part II—Southern Area—(London, 1909), Matthews gives charts in which all the available hydrographic observations for 1904 and

* Matthews, *Report on the Physical Conditions in the English Channel*, 1903. *First Report of the North Sea Fisheries Investigation Committee (Southern Area)*, London, 1905.

† *Meddelelser fra Kommissionen for Havundersögelser. Hydrografi*, Vol. I., No. 9, Copenhagen (1907).

1905 are plotted and isohalines drawn which seem to bear out his contention that a current of water of low salinity is flowing southwards from the Irish Sea.

I have re-drawn the charts (see Plates II to V) putting in the numerical values for the salinities of the various points indicated on Matthews' charts. Nearly all of the numerical data are given in the above-mentioned Second Report, Part II, but a few of them had to be obtained from the Second Report, Part I—Southern Area—(London, 1907), while a few were obtained from the "Bulletins trimestriels du Conseil permanent international pour l'exploration de la Mer" for 1905. A few other figures, not utilised apparently by Matthews, but also referring to the same period, were found in Part I of the Second Report. These have also been introduced into the charts of the present paper, but are specially indicated. I have tried to draw the isohalines on the charts as fairly as possible, and have also indicated by dotted lines how Matthews draws the same. It seems to me that my way of drawing the lines is in better agreement with the figures, and also gives a reasonable explanation of the facts, but it must, of course, be admitted that the data are too scanty to enable one to draw the isohalines with any great certainty.

It will be seen at once that the isohalines indicate a current of water flowing northwards up the Irish Sea with a tendency to strike St. David's Head. At the same time there is a small tongue of low salinity water coming South round Land's End. It was the presence of this water which led Matthews to think that there was a southward flowing current from the Irish Sea.

This tongue of water seems, however, relatively insignificant, and is almost certainly derived not from the Irish Sea, but from the Bristol Channel, and is probably

carried southwards by an eddy resulting from the tongue of Gulf Stream water striking St. David's Head and being diverted southwards as indicated in the figure. The fact that this tongue of fresher water is much less prominent, and even cut off altogether by salter water towards the end of the year, when the Gulf Stream Drift is at a minimum, is in good agreement with this view. It would evidently be exceedingly interesting to study the hydrographic conditions in the Bristol Channel, and future work should also carefully look for the narrow tongue of salt water running across its mouth.

It seems probable that the above-mentioned eddy would only be sufficiently strong to carry Bristol Channel water southwards during the spring, when the Gulf Stream Drift is at a maximum. It appears that along the North coast of Cornwall sand accumulates on the western side of the headlands,* which indicates that the total movement of the water towards the North-east is greater than any movement to the South-west.

The conditions during 1904 seem to have been somewhat different from those found during 1905, but the data available are somewhat scantier than for the latter year. I have also re-plotted the charts for 1904, but do not give the results in this paper, as they are too doubtful. The isohalines, as drawn by Matthews in the charts for 1904, do not disregard the values of the salinities at some of the stations, as in the 1905 charts, but it is also possible to draw them somewhat differently and bring them more into line with those for 1905, as re-drawn in the present paper. When this is done, islands of fresher water to the South of the Land's End appear in the charts for August and November somewhat similar to that in the chart for

* I am indebted to the Rev. W. Milburn Briggs for this information.

November, 1905. The tongue of salter water passing up the Irish Sea seems to be much less pronounced than in 1905, and the charts also seem to suggest that in 1904 the Gulf Stream Drift struck the Land's End instead of striking against St. David's Head. This is also rendered more probable by Gough's observations " On the distribution and the migrations of *Muggiaea atlantica* (Cunningham) in the English Channel, the Irish Sea, and off the South and West Coasts of Ireland in 1904."*

Only a few isolated hydrographic observations made by the " Helga " in the Irish Sea during 1905 have been published (Bulletins trimestriels). During 1909, however, the " Helga " made a detailed hydrographic survey of the whole Irish Sea with the exception of the portion to the East of the Holyhead-Calf of Man line which we have been investigating from Liverpool since 1906. This hydrographic work was carried out under the direction of Mr. E. W. L. Holt, of the Irish Department of Agriculture, and Mr. Holt has very kindly given me permission to make use of his figures (which will be published in the Bulletins trimestriels for the current year). I have, therefore, introduced Holt's and our own figures for 1909 on the same charts as Matthews' figures for 1905, as no figures for a date later than 1905 are available for the southern area.

It is evident that the curves drawn for 1909 are not directly comparable with those drawn for 1905, and to make this clear on the charts a narrow uncoloured strip has been left between the two sets of curves. Although this combination of the two sets of curves may be open to criticism, it is useful for our present purpose of discussing the flow of water through the Irish Sea. The figures and

* *Publication de Circonstance, No. 29, du Conseil permanent international pour l'exploration de la Mer.* Copenhagen, 1905.

curves in the Irish Sea speak, I think, for themselves. It would hardly be possible to draw the isohalines substantially different from the way in which they are drawn on the charts, and it is clear that such a distribution of salinities can only be explained by a flow of water from South to North.

The figures on the charts refer to surface salinities, but the Irish Sea is practically homosaline throughout, and where any differences of salinity with depth do occur they are small, and do not affect the above conclusions. The isohalines show very plainly how the northward flowing current tends to flow along the eastern side of the Irish Sea. They also show that a great deal of the water flows round to the east of the Isle of Man (as indicated also by the tides). In this last connection it is most interesting to note that whereas the spring maximum of the salinities is well marked at Stations V, VI, VII and XI, between the Calf of Man and Holyhead, it is practically undetectable at stations on the 54° of latitude West of the Calf of Man. This probably means that nearly all the water flowing through the Irish Sea passes to the East of the Isle of Man. It is to be noted that in my report for 1908, where I also referred to this last point, there is an error in the third paragraph from the bottom of the last page but one—" the 34·0 isohaline on the chart " should read " the dotted line on the chart."

The curves of equal temperatures for the surface water of the Irish Sea during 1909 have been drawn and discussed by Mr. Johnstone, and are reproduced in the plates illustrating his paper in the present report. These isotherms show even more strikingly than the isohalines the direction of flow of the water. In particular they clearly show the current bending round to the East of the Isle of Man.

Fig. 22. Chart illustrating the probable directions of the currents in the Irish Sea and Bristol Channel at the time when the Gulf Stream Drift is at a maximum.

EXPLANATION OF PLATES.

PLATE II. *Surface Salinities, February.*

Figures to the South of the white line refer to the period Feb. 1-10, 1905, unless there is a note to the contrary.

Figures to the North of the white line, and West of the line Calf of Man-Holyhead, have been communicated to us by Mr. E. W. L. Holt, and refer to the period Feb. 1-19, 1909. (A few figures referring to 1905 are also specially indicated.)

Figures to the East of the line Calf of Man-Holyhead are our own, and refer to the period Jan. 25-29, 1909. The salinity, 34·43 at 52° 46′ N.; 5° 38′ W. is that at 31 metres.

PLATE III. *Surface Salinities, May.*

Figures to the South of the white line refer to the period May 1-16, 1905, unless there is a note to the contrary.

Figures to the North of the white line and West of the line Calf of Man-Holyhead are Mr. Holt's, and refer to the period May 3-10, 1909. (A few figures referring to 1905 are also specially indicated.)

Figures to the East of the line Calf of Man-Holyhead are our own, and refer to the period May 17-19, 1909.

PLATE IV. *Surface Salinities, August.*

Figures to the South of the white line refer to the period Aug. 1-16, 1905, unless there is a note to the contrary.

Figures to the North of the white line, and West of the line Calf of Man-Holyhead, are Mr. Holt's, and refer to the period Aug. 2-10, 1909. (A few figures referring to 1905 are also specially indicated.)

5°

Plate II


Surface Salinities. February
Dublin
Isle of Man
Solway Firth
Morecambe Bay
Fleetwood
Liverpool
Holyhead
Anglesea
Rockabill
Lambay I.
Tuskar
Cardigan Bay
St. David's Head
Bristol Channel
Lundy I.
Fastnet
C. Clear
Scilly Is.
Plymouth
FRANCE
35·40 Matthews
35·20 Matthews
35·30 Matthews
35·50 Matthews


55°

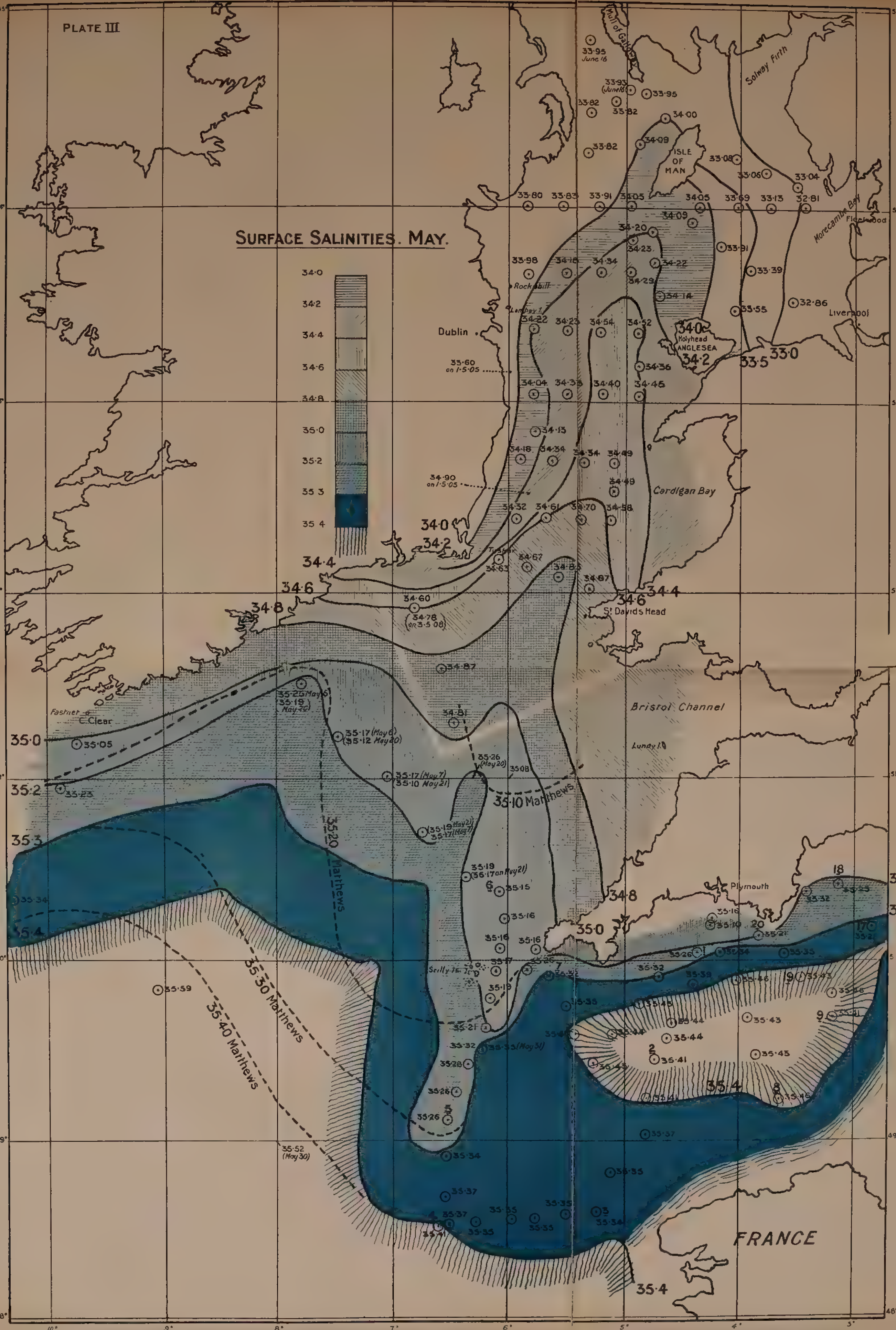


PLATE III
SURFACE SALINITIES. MAY.
Dublin
ISLE OF MAN
Solway Firth
Morecambe Bay
Fleetwood
Liverpool
Holyhead
ANGLESEA
Cardigan Bay
St. Davids Head
Bristol Channel
Lundy I.
Plymouth
Scilly Is.
Fastnet
C. Clear
FRANCE
35·10 Matthews
35·20 Matthews
35·30 Matthews
35·40 Matthews

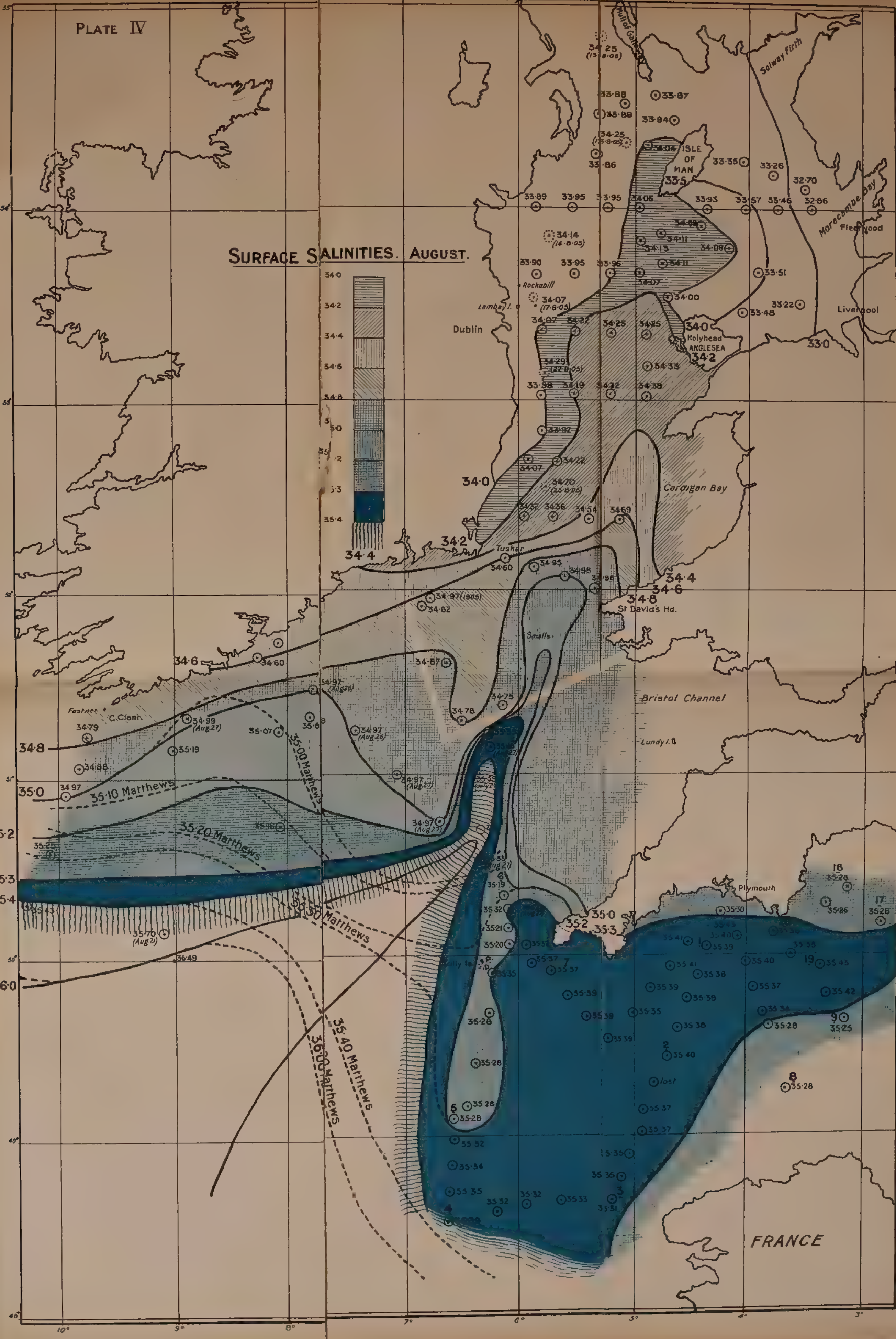
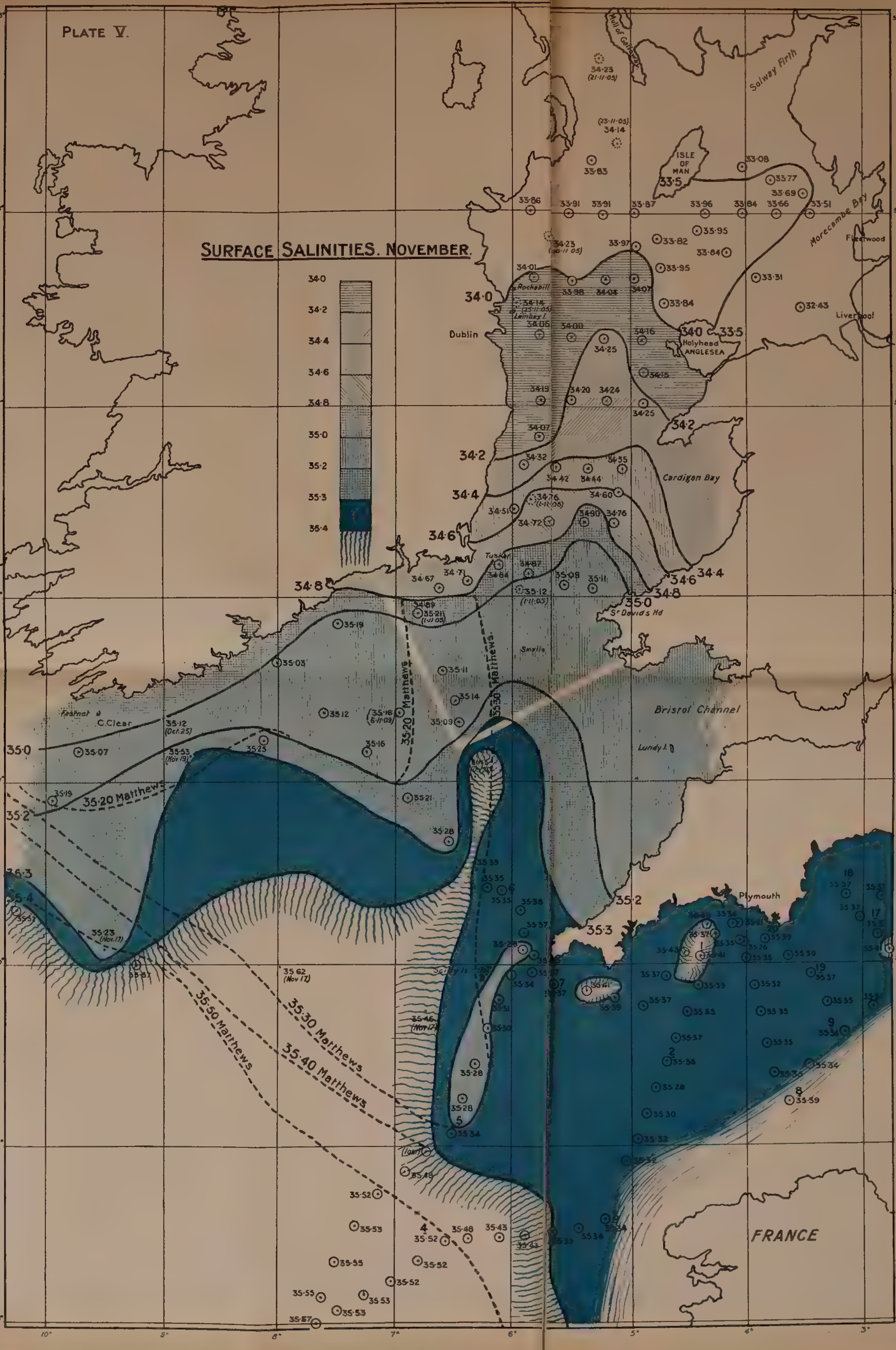


PLATE IV
SURFACE SALINITIES. AUGUST.
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.3
35.4
ISLE OF MAN
Solway Firth
Morecambe Bay
Fleetwood
Liverpool
Holyhead
ANGLESEA
Dublin
Rockabill
Lambay I.
Cardigan Bay
Tuskar
St David's Hd.
Smalls
Bristol Channel
Lundy I.
Fastnet
C. Clear
Plymouth
Scilly Is.
FRANCE
35.10 Matthews
35.20 Matthews
35.30 Matthews
35.00 Matthews
35.40 Matthews
36.00 Matthews

PLATE V.


SURFACE SALINITIES. NOVEMBER.
Solway Firth
Mull of Galloway
Isle of Man
Morecambe Bay
Fleetwood
Liverpool
Dublin
Rockabill
Lambay I.
Holyhead
ANGLESEA
Cardigan Bay
Tuskar
St Davids Hd
Smalls
Bristol Channel
Lundy I.
Fastnet
C. Clear
Scilly Is
Plymouth
FRANCE
35·20 Matthews
35·30 Matthews
35·40 Matthews
35·50 Matthews

Figures to the East of the line Calf of Man-Holyhead are our own, and refer to the period July 26-28, 1909. The figures for 54° 33′ N., 5° 17′ W. and 54° 38′ N.; 4° 56′ W. refer to a depth of 18·3 metres.

PLATE V. *Surface Salinities, November.*

Figures to the South of the white line refer to the period Nov. 3-22, 1905, unless there is a note to the contrary.

Figures to the North of the white line, and West of the line Calf of Man-Holyhead, are Mr. Holt's, and refer to the period Nov. 1-6, 1909. (A few figures referring to 1905 are also specially indicated.)

Figures to the East of the line Calf of Man-Holyhead are our own, and refer to the period Nov. 1-4, 1909.

In all the above plates the figures to the South of the white line have been taken from Matthews' reports (*loc. cit.*). Figures used by Matthews in drawing his isohalines are marked by a dot and circle. Figures given in his tables, but not, apparently, utilised for the charts, are marked by a dot alone.

A small underlined figure indicates that the station is one at which samples from various depths are collected; the number in these cases is the number of the station in the "Bulletins trimestriels du Conseil permanent international pour l'exploration de la Mer."

REPORT ON TEMPERATURE OBSERVATIONS IN THE IRISH SEA DURING THE YEAR 1909.

By Jas. Johnstone.

The main results obtained from the periodic hydrographic cruises made during 1909 are tabulated and discussed by Dr. Bassett in a preceding Paper in this Report, but I wish to give an account of the temperature observations in particular, including data other than those obtained in the course of the periodic cruises. Special attention was directed towards obtaining a series of records which might enable us to plot, with some probability, the course of the isothermal lines in the eastern part of the Irish Sea. This part of the hydrographic work was regarded as of considerable importance, apart altogether from the question of the circulation of water in the Irish Sea and St. George's Channel, since it is highly probable that the distribution and migrations of some fishes are to be associated with the annual temperature range on the various fishing grounds.

The Data. As in 1907 and 1908, copies of the semi-diurnal temperature observations made from the principal West Coast Light Vessels have been supplied by the Meteorological Office, and these are tabulated on page 245. The observations made at 4 p.m. are alone considered. Those from the Cardigan Bay Light Vessel are not included since they were discontinued in 1909. Monthly averages have been calculated. The latter have not been graphed in this Report.

The table immediately following that just mentioned gives the temperatures of the sea at the surface at the Hydrographic Stations. In addition to the quarterly cruises a series of observations were also made at inter-

mediate times, except in December, when pressure of other work prevented us from making the cruise. The same stations, with one or two exceptions, were visited on all these occasions; and not only were the usual observations made, but surface temperatures were also taken at positions nearly intermediate to those of the regular stations. These latter data are not tabulated, but they are plotted in the series of sketch charts showing the surface isotherms. As a general rule, Richter thermometers were used to take surface temperatures, but a "Kiel" thermometer was employed at stations other than the "hydrographic" ones. The error of this instrument (about 0°·15 C.) was frequently determined, and its readings are corrected. Deep temperatures were sometimes taken by means of a Richter Reversing thermometer of the latest pattern, used on the Nansen-Pettersson water-bottle frame. The readings of the latter instrument always agreed with those of the Nansen deep-sea thermometer used in the water-bottle, and in the end the latter only was used; and this procedure seems to be preferable as there must always be some degree of uncertainty attached to the readings of a reversing thermometer, no matter how perfectly made, when used alone. The water-bottle was necessarily worked from the windward side of the ship, the latter being brought into position. Surface water samples for the determination of temperatures were always taken from the leeward side: this was the practice, though I do not suppose there would have been a perceptible difference in temperature on the two sides of the vessel.

In addition to data obtained in this way, I have also considered observations made on board the "James Fletcher" in the course of her ordinary patrol work. The surface temperature is taken hourly when the vessel is at

sea, and the data thus obtained have been of the greatest value. I give these (corrected) readings for a number of coastal stations. It is, of course, evident that these data cannot tell us very much concerning the circulation of water, influenced as they are by proximity to the land. It is, however, necessary that we should know the sea temperature at coastal stations, when we attempt to consider physical changes in the sea in relation to the fishery periods, for it is near to the coast that some of the most important local fishing grounds are situated. It will be noticed that four of these coastal stations are situated very closely to each other; they are:—South Stack, Carmel Head, Middle Mouse Island, and Pt. Lynas. There are no fishing grounds adjacent to these parts of the coast, but they are of importance since the North-easterly drift of water in the Irish Sea appears to be concentrated to the North and East of the Island of Anglesey, and it was desired to record the temperature hereabout with as much precision as possible. The positions of most of these stations are indicated in the chart on p. 223.

Hourly observations are also made on traverses across Liverpool Bay, and across the Welsh Bays, but these are not included in our published tables.

Our own observations are necessarily restricted to the Eastern side of the Irish Sea, to the sea round the Isle of Man, and to the Welsh bays, with the exceptions of occasional incursions into Scottish waters. It has been our privilege* to be allowed to make use of the salinity and temperature observations made by the Irish Department of Agriculture and Technical Instruction, on the Western side of the Irish Sea and in St. George's Channel, and without these data it would have been

* For which we are indebted to Mr. E. W. L. Holt.

Fig. 23. Hydrographic Stations in 1909.

impossible to draw the isotherms, even those strictly relating to Liverpool Bay.

Interpolation. It is quite necessary to interpolate values for the surface temperatures, when drawing the isotherms over a large area, since it is not generally practicable to make the observations during a period of time short enough to preclude the possibility of a change of temperature. Even in the Western side of the Irish Sea it has not been possible to visit all the stations considered during the same cruise; and it was not always practicable to arrange that the cruises of the "Helga" and the "James Fletcher" should be made during the same days. Since the stations visited by the former vessel are much more numerous, and cover a larger area than the Lancashire ones, they have been taken as the basis for the construction of the isotherms, and the observations made on the English side of the Channel have been reduced so that they represent the temperatures which were, probably, characteristic of the sea during those days on which the "Helga" made her observations. Just how best to reduce these observations was a matter of some little difficulty. I tried at first to make use of the now well-known formula for interpolation suggested by D'Arcy Thompson,* that is

$$f(t) = A_0 + A_1 \sin(\theta + e_1) + A_2 (\sin 2\,\theta + e_2) + \&c.$$

In this expression the time is regarded as an angle, the year being supposed to consist of 360 days, and the temperature at any date is then a function of the sine of the angle. Now if we had only four observations for the whole year, these observations being made at the times of the maximum, minimum, and half-amplitude, this formula would afford the only possible means of inter-

* *Report (Northern Area) on Fishery and Hydrographical Conditions in the North Sea and adjacent waters.* (1904-1905); Cd. [3358], p. 186, 1907.

polating values for intermediate times, since, obviously, many curves could be drawn through the four given points. It has, indeed, been shown* that such interpolated values would really be very accurate. They would not take account of the " accidental " variations in sea temperature resulting from unusual winds, or the operation of other factors, but would express only the generalised annual temperature wave, which is indeed all that one attempts in most discussions of such variations in regard to the sea fisheries. It is assumed that the August sea temperature is that of the maximum, the February one that of the minimum, and the May and November ones those representing the half-amplitudes of the annual wave. But whenever we have more than four observations, or when, as in the present investigation, the date of the cruises do not coincide with those times when we have reason to suppose that maxima and minima occurred, then the sine-function must be used cautiously in interpolation. The first Lancashire cruise had to be made at the end of January, and the third at the end of July, and we know, from other observations, that the actual minimum fell in February and March, while the maximum was in August. If, then, the above formula had been employed, inaccurate results would have been obtained, since the constants would have been incorrectly deduced.

I have, therefore, resorted to graphic interpolation. We have daily observations for the various light vessel stations, so that a smooth curve drawn as closely as possible to points representing the monthly mean temperatures will give a very reliable picture of the annual variations. The observations made at the Carnarvon Bay light vessel are regarded as indicating the variation in

* *Ibid.* p.186-8

temperature of the water of the Irish Sea unaffected by the influence of the land. It is very probable that this is the case, and that the water here has much more an "open-sea" character than in any part of the Irish Sea North of the latitude of Anglesey. Conversely, the Morecambe Bay and Liverpool North-west Light Ship sea temperatures may be regarded as affected by the influence of the land: those taken at the Bahama Bank vessel are intermediate between the two series mentioned. The Lancashire observations at stations 3, 4, 5, 6, 7, 11, 12, 13, 15, have therefore been corrected by just that difference which is shown on the curve for the Carnarvon Bay series, between the mean dates of Lancashire and Irish cruises. The observations made at the other stations have been similarly corrected from the Morecambe Bay Light Vessel series.

The temperatures taken at the coastal stations have been reduced to monthly means, and then smooth curves have been drawn. In the case of most of these stations the series is fairly complete, except in one or two months. Values for these dates have been obtained graphically, since interpolation formulæ, such as those employed in the evaluation of mathematical functions, cannot easily be applied. The method of graphing a number of such series suggested by D'Arcy Thompson* is of the greatest value, and has been employed in the present investigation. A number of stations, which we have reason to believe are associated together, inasmuch as the variations from one to another are in the same direction, are grouped, and the monthly temperature means are plotted to the same axes of co-ordinates. Fig. 24 represents such a family of curves, that for Red Wharf Bay being taken as the standard one. The values of the ordinates for each of the

* *Ibid.* p. 172.

others change regularly by 1° C., as indicated in the margin. The latter values have to be added or subtracted. One is guided, in drawing the smooth curve, by the way in which the adjacent ones run, and by using some judgment, and having regard to what one knows of the

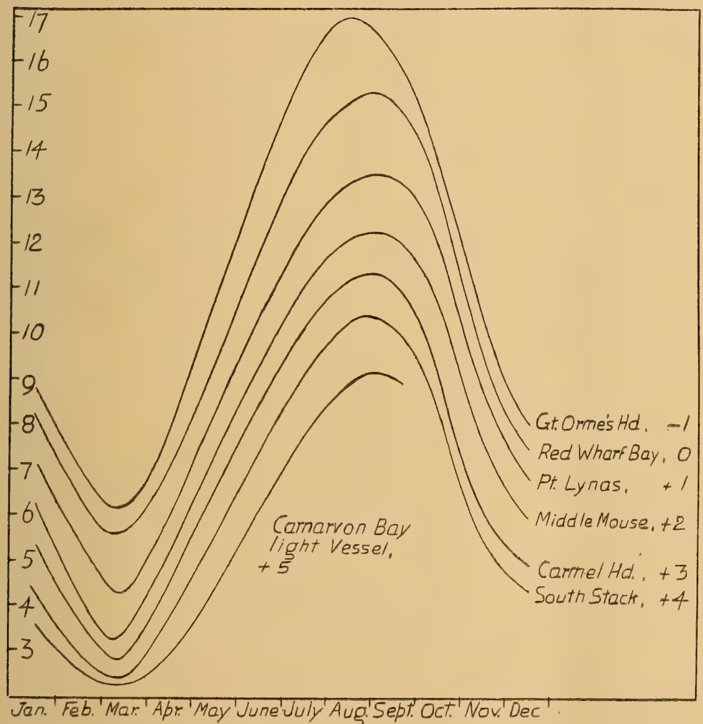


FIG. 24. Surface temperatures at various inshore stations in 1909.

physical conditions obtaining at each station. We see at once that a good deal of confidence can be placed in these curves, and that we may interpolate from them with a reasonable expectation of accuracy. Such curves have been made for all the coastal stations, and in drawing the

isotherms the temperatures for the mean dates in question have generally been obtained from them.

Temperature Stratification.

There are no reasons for modification of the statement made in last year's Report that the Irish Sea is a practically homothermic water mass, showing no significant variation of temperature with depth. The data relating to the hydrographic soundings are tabulated in Dr. Bassett's Report, and it will be seen that the variations of temperature with depth of water are small and inconstant. Such as they are, they appear to me to depend entirely on (1) convection currents set up by the chilling of the surface waters, and (2) lateral shore drifts set up by winds, and by the relative differences in temperature near and remote from the shore. It has been pointed out that as the coastal water heats up in summer at a greater rate than the off-shore water, it must tend to stand at a higher level, and thus off-shore currents or drifts must be set up at the surface, while deep currents set in towards the land to restore equilibrium. Obviously these off- and on-shore drifts will be partially, or perhaps entirely masked by the influence of the tidal streams. Further, there is the strong effect of the latter in conveying masses of heated or chilled water to and from the shore. The Irish Sea and St. George's Channel are a relatively shallow water area, and the northerly drift through this is too weak to set up notable temperature or salinity, stratification. We find, then, that at stations 5, 6 and 7 the differences in temperature between surface and bottom water never amounted to more than 0·7° C., and were usually much less. The greatest differences detected were at stations 1 to 4 during the June cruise, during and after a spell of fine weather, when the bottom water was

in one case 2·83° C. lower than that of the surface, and in all four cases over 1° in amount. But the July cruise, some six weeks later, disclosed very different conditions, for the mean difference then was less than 0·3° C. This cruise was made after a week of rather exceptional weather, when the wind had been blowing at times with the force of a gale, the result being that the water over the whole area investigated had become mixed up, practically obliterating the differences previously existing. This effect of a storm in relatively shallow water has been pointed out by Krümmel,* in the case of the Baltic Station "D Ostsee 7," where, after an interval of two days of stormy weather, the temperature difference between surface and bottom had practically been reversed, the mean remaining about the same. In the Irish Sea, then, a spell of calm, warm weather leads to the heating of the surface layers and the establishment of a condition of spurious stratification. Significant vertical temperatures are not to be detected anywhere between Britain and Ireland, as is shown by the numerous soundings made all down the Channel by the "Helga" in 1909. Only in the stations South from the Tuskar were such disclosed. At the Irish station, 51° 55′ N, 6° 49′ W, there was a difference of nearly 5° C. at a depth of 64 m. and at 51° 22′ N., 7° 0′ W., a difference of 8·2° C. at a depth of 119 m. This was in August. The soundings, during the same cruise, in the fairway of the Channel between Mull of Galloway and the Tuskar showed differences of just the same order as those we found between Calf of Man and Holyhead at about the same time.

The Surface Temperatures in 1909.

At the minimum; mean date, February 15th, 1909. The surface temperatures are represented by the sketch

* *Beteilig. Deutschlands a. d. Internat. Meeresforsch. III Jahresber.* Berlin, 1906, p. 19.

chart, fig. 25, p. 230. This has been plotted from our own observations and from data supplied by Mr. Holt. The

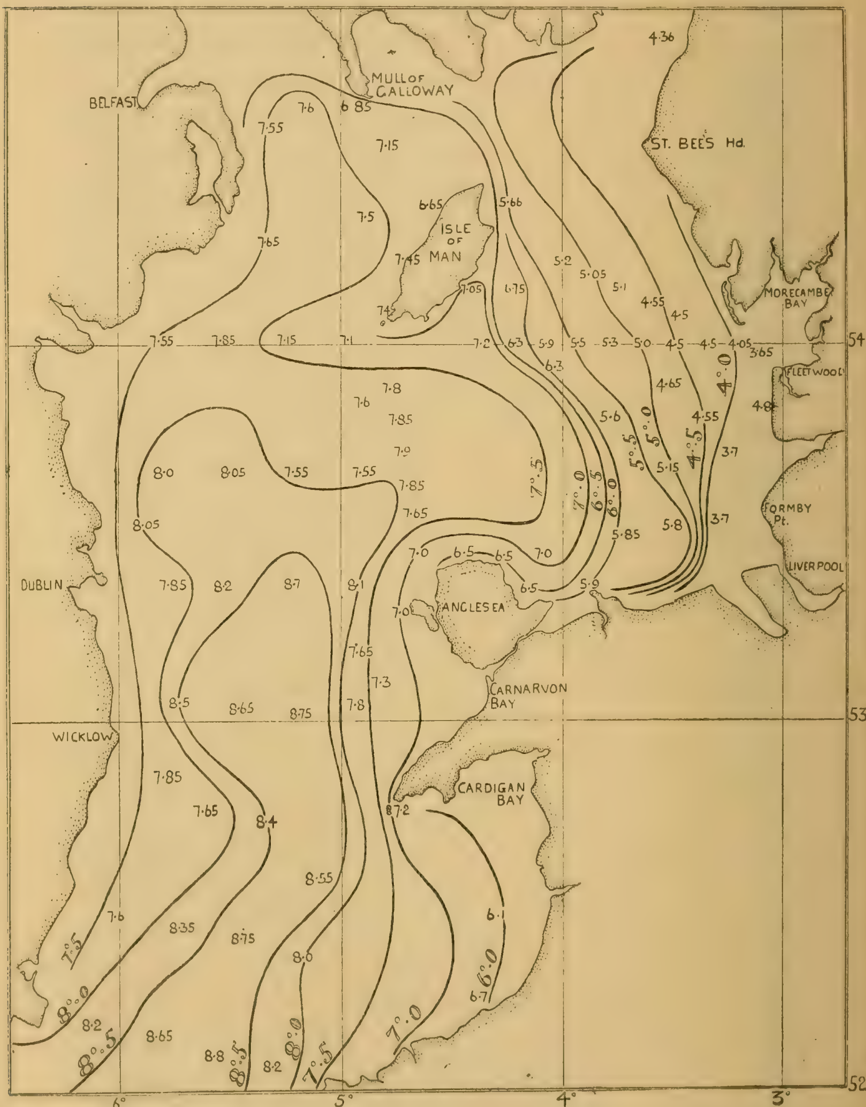


Fig. 25. Probable isotherms in the Irish Sea and St. George's Channel on 15th February, 1909.

courses of the isotherms in the region North-east from the Isle of Man are rather conjectural, for there are no observations with the exception of those from the Solway Light Vessels. South-west from the Isle of Man the observations are fairly numerous, and enable us to draw the isotherms with some degree of accuracy; while, because of the greater uniformity of conditions in the Channel between Ireland and the West coast of England and the Isle of Man, the observations there, though fewer in number, are still sufficient to determine the main distribution of temperature. It is questionable whether more numerous observations would make the task of plotting the isotherms any easier. If we had a continuous record of surface temperatures we should probably find that minor irregularities would lead to dovetailing of the contour lines, and the formation of "islands" of hotter or colder water. The isotherms are to be regarded as of the nature of smoothed curves, and probably represent fairly the main facts of the distribution.

The warmest part of the area in February, 1909, was that part of the Channel in the fairway between the Tuskar-Bishops line, and the latitude of Anglesey; and the surface temperatures there varied from about 8·5° to 9°. The coldest region was that extending from Air Point, in Cheshire, to the mouth of Morecambe Bay; over the greater part of this area the temperature was less than 4°. The central part of the Irish Sea was characterised by great uniformity, the variation being less than 1°. It will be seen that the isotherms bend round to the North-east of Anglesey rather sharply, and that the temperature gradient is steepest here. If a line be drawn passing through the isothermal lines where the curvature is greatest, it will be seen that this would correspond very approximately to the axis of the Gulf Stream Drift, as

represented in Dr. Bassett's figure on p. 217. But the cooling effect of the shallow water and banks off the coasts of Cheshire and Lancashire is so great at this time of the

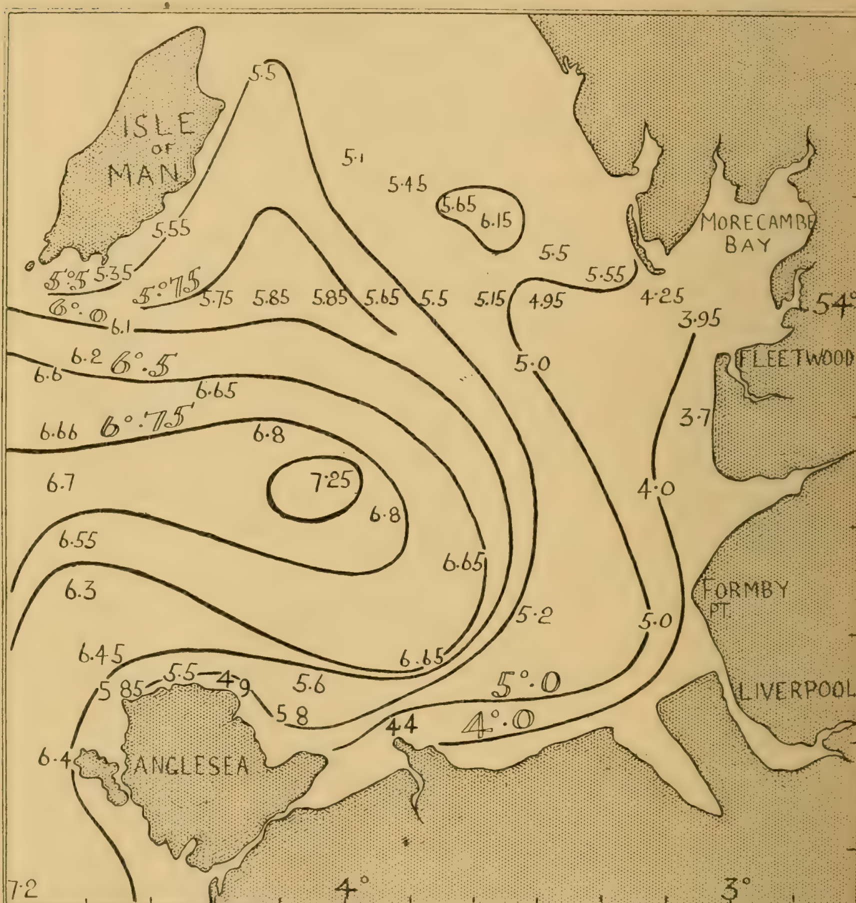


FIG. 26. Probable isotherms in the eastern part of the Irish Sea on 20th March, 1909.

year as practically to obliterate any indications of the further flow of water Northwards along the West coast of England.

March 16th, 1909.

The data on this occasion are those of an intermediate cruise, and there are no observations for the Irish Sea to the West of the Calf-Holyhead line. But it will be seen at once from fig. 26, which represents the isotherms at this date, that the main factor affecting the distribution of temperature is the flow of water to the North-east. The mean temperature of the whole area of sea to the East and South-east of the Isle of Man is very much the same as it was in February, and that of the sea immediately adjacent to the coasts of North Wales, Cheshire and Lancashire is rather less than in the former month. But the isotherms are now curved more sharply into Liverpool Bay, towards which their axes are directed, and just North from Red Wharf Bay the gradient is very steep. It will also be seen that there are now indications of a flow of water to the North-west from the coast of Lancashire, and also along the East side of the Isle of Man. This latter drift is, however, comparatively feeble, and the main drift of water from St. George's Channel appears to be to the East, round the coast of Anglesey, and then to the North from the estuary of the Ribble.

May 6th, 1909.

Fig. 27 represents the distribution of temperature at the beginning of this month, and is constructed from observations made over the entire area. There is greater uniformity of conditions in this month than at any other period of the year, and this is due to the fact that the influence of the land is now exerted in the opposite direction, as compared with the conditions in February and March. The Gulf Stream Drift appears to have attained its maximum development at the beginning of this month, but the flow of water round Anglesey is not

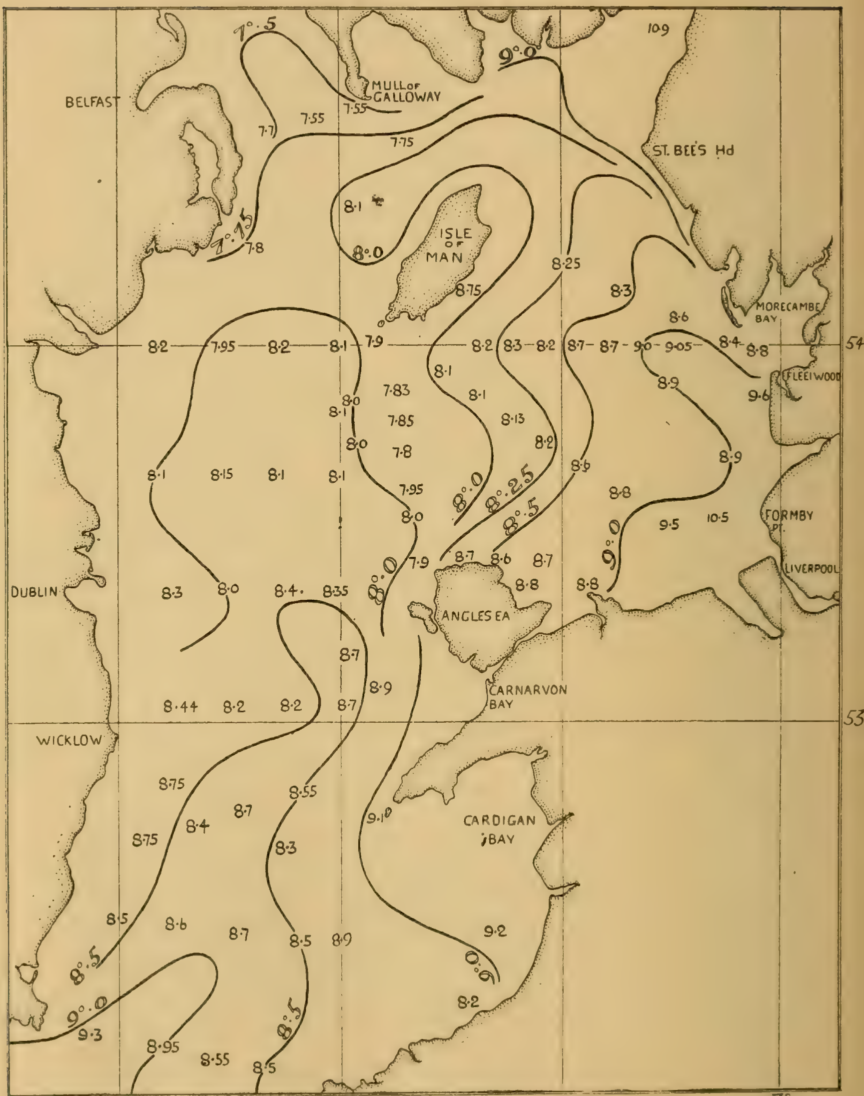


Fig. 27. Probable isotherms in the Irish Sea and St. George's Channel on 6th May, 1909.

so clearly indicated by the direction of the isotherms, because the positions of the latter are affected by heating up of the water oscillating towards and from the banks off the Cheshire and Lancashire coasts. It is quite clear, however, that there is now a general translation of warm water from Liverpool Bay along the Lancashire coast, and then to the North-west, and there are distinct indications of the flow of this water round Point of Ayre, in the Isle of Man, towards the North Channel. It is also clearly evident, from this and the previous charts, that the northerly drift of water from St. George's Channel slackens at about the latitude of the Calf of Man, and that the sea West and South from this point is a relatively stagnant area. It is also apparent that South from the Calf of Man, towards Holyhead, the water is rather colder than in the fairway of the Channel, to the West, and towards the West coast of England on the East. There is the same increase of temperature, passing down channel from Anglesey, as is indicated in the previous charts.

June 16th, 1909.

The observations made in this month were those of an intermediate cruise which was extended into the North Channel and Firth of Clyde. The number of stations which were investigated North from the Isle of Man were, however, very few, and I have made no attempt at drawing the isotherms further North than adjacent to the Isle of Man. The temperatures have been plotted in fig. 28, and it will be seen that a very large part of the Eastern half of the Irish Sea is now filled with relatively warm water which is apparently drifting to the North-west. In the charts representing the conditions in February, March and May the isotherms were generally

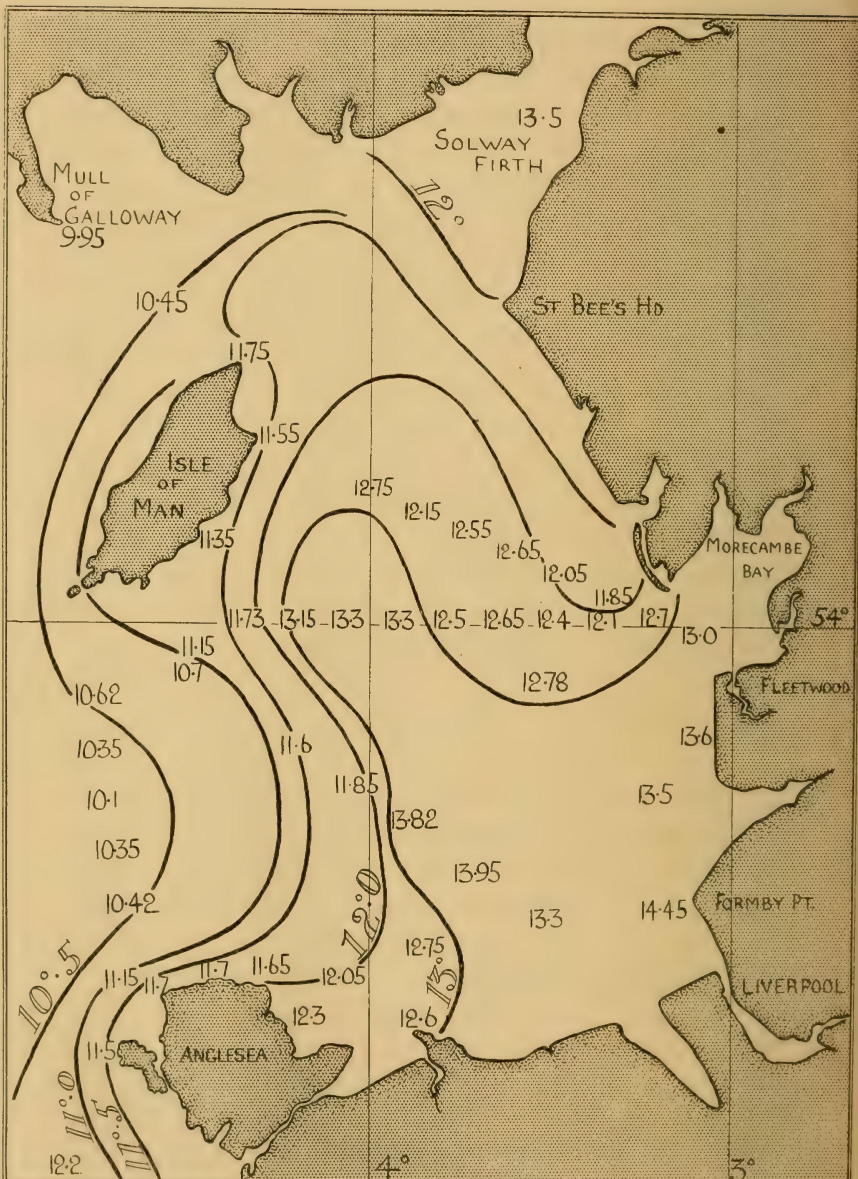


FIG. 28. Probable isotherms in the eastern part of the Irish Sea on 16th June, 1909.

convex towards the English coast: they are now convex towards the North-west, except immediately to the North of Anglesey, where the prevalent drift to the North-east is still indicated. During this cruise there was a marked difference between the temperatures of surface and bottom water, the former being significantly warmer, and this is due, of course, to the heating effect of the sand-banks along the Cheshire and Lancashire coasts. Nevertheless, the direction of curvature of the isotherms indicates that this heated water is gradually being displaced to the North-west, passing round Point of Ayre into the North Channel, and the direction of curvature of the isotherms in the neighbourhood of Anglesey indicates just as clearly that the cause of this displacement is the continual entrance of colder water from St. George's Channel. It will also be seen that there are no longer any indications of a flow of water immediately along the East coast of the Isle of Man, the strength of the Gulf Stream drift being now much less than in the Spring months.

August 4, 1909.

Fig. 29, which represents the distribution of surface temperatures during part of this month, has been constructed from our own and Mr. Holt's observations, and includes the whole area. It represents very nearly the conditions during the period of annual maximum temperature. The distribution is now entirely reversed, the colder waters being those of the centre of the Irish Sea, and in the fairway of St. George's and North Channels, while the warmest waters are those off the coasts of England and Wales. All the coastal waters within the territorial limits from Great Orme's Head to the Solway Firth are over 16° in temperature, and though we have no

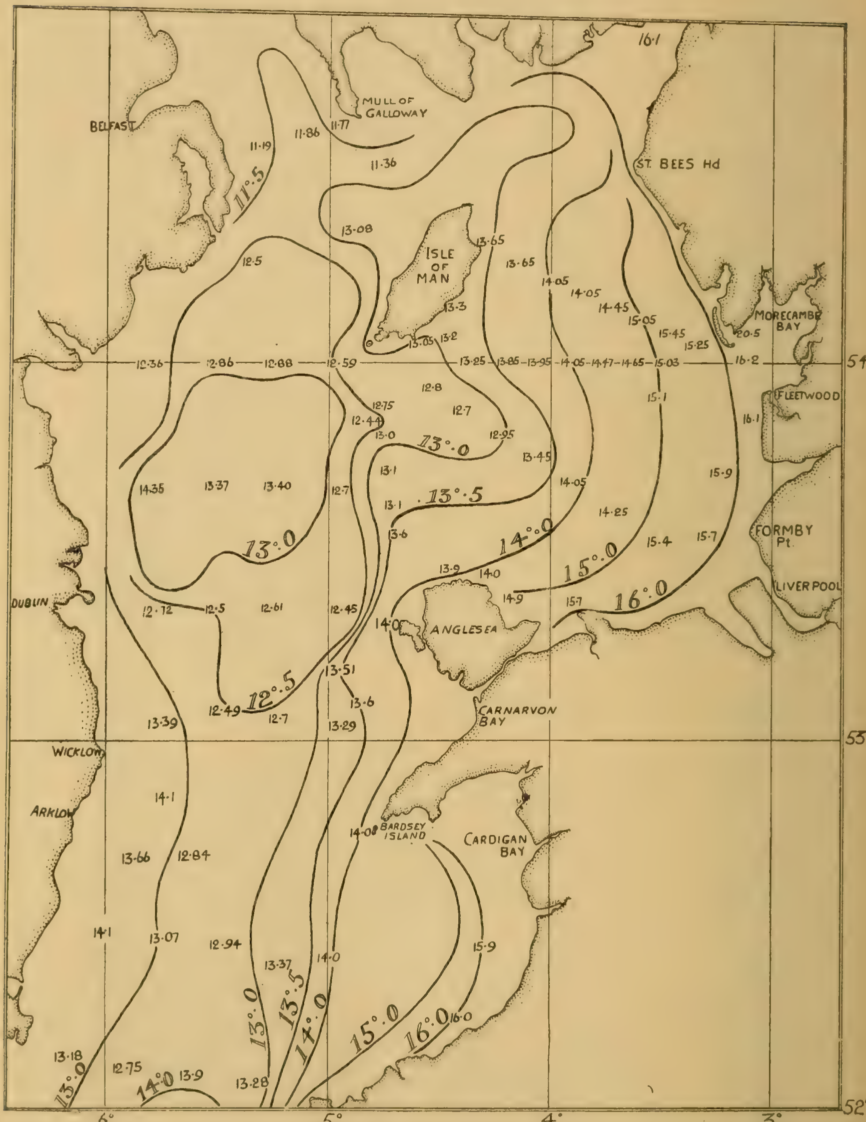


FIG. 29. Probable isotherms in the Irish Sea and St. George's Channel on August 4th, 1909.

actual observations for this period of the year, it is probable that temperatures of 17° to 18° characterise the water in Tremadoc Bay. Round the North Coast of Anglesey the temperature is very little higher than that in the fairway of the Channel, because the water of this part of the coast is deep, and affected to a relatively slight extent by the land, and also because of the continuous flow round the promontory of Anglesey. It will be seen that a large part of the Irish Sea South and West of the Isle of Man is now filled with water which varies in temperature from 12·5° to about 13°, and inside this is a smaller area, the temperature of which appears to be a little greater. This warm "island" of water is established, no doubt, because of the general deficiency of circulation in this part of our area. In all the former charts this relatively stagnant area was situated nearer to the Isle of Man, but in August, when the strength of the Gulf Stream Drift is nearly at its minimum value, the part of the Channel covered by non-circulating water has increased greatly in area. It should also be noticed that in these months, when the Gulf Stream flow is weakest, the curving-in of the isotherms towards Liverpool Bay occurs closer to the Isle of Man than the Anglesey coast. When the flow is strongest the water tends to pass closely round Anglesey. Then, just as at the time of minimum temperature, the isotherms in the eastern part of the Irish Sea run approximately parallel to the coast line.

September 15th, 1909.

The observations at this time related to an intermediate cruise, and only the eastern side of the Irish Sea was investigated. The temperatures are again very uniform, the greatest difference being only 1·65° The

14° isotherm runs approximately parallel to the coast of Lancashire, but, just as in May and June, there are again indications of the North-westerly flow of warm water from Liverpool Bay.

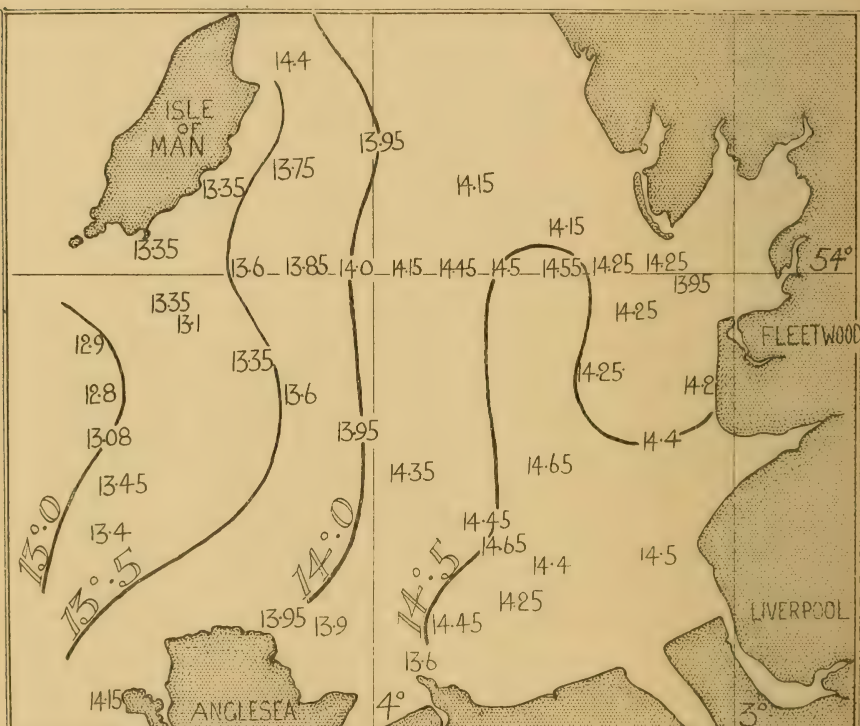


FIG. 30. Probable isotherms in the eastern part of the Irish Sea on 15th September, 1909.

November 3, 1909.

The data are those collected during a quarterly cruise and represent both our own and Mr. Holt's observations. The temperatures are plotted in fig. 31, and the isotherms are drawn. With the exception of one or two indications of "islands," and what appears to be an unusually high

sea-temperature to the North-west of the Isle of Man, the distribution of warm and cold water appears to be quite normal.

General Observations.

A study of the charts showing the approximate courses of the isothermal lines during 1909 appears to me to afford additional arguments in favour of the view of the circulation of water in the Irish Sea, taken up by Dr. Bassett in the preceding paper, that the general drift of water, both at the surface and bottom, is from North to South through St. George's Channel, to the East close to the coast of Anglesey, and then to the North-west round Point of Ayre through the North Channel. This view is supported both by the study of isohaline and isothermal contour lines, and it will be seen that these mutually confirm each other when we remember that each series may vary independently of the other.

One sees quite clearly (1) that in St. George's Channel the isotherms, except so far as they run parallel to the coast lines, are convex towards the North; and, particularly in February and May, are bent over to the East towards the coast of Anglesey, where the temperature gradient is steeper than on the Irish side; (2) that this convexity of the isotherms is greatest to the North and North-east of Anglesey, a condition again best marked in February, March and May; and (3) that the isotherms East of a line joining Calf of Man and Holyhead are convex towards the English coast in the southern part of the area, and convex towards the Isle of Man in the northern part of the area. It is only in September, when the temperature throughout is very uniform, that this arrangement of the isotherms is obscured.

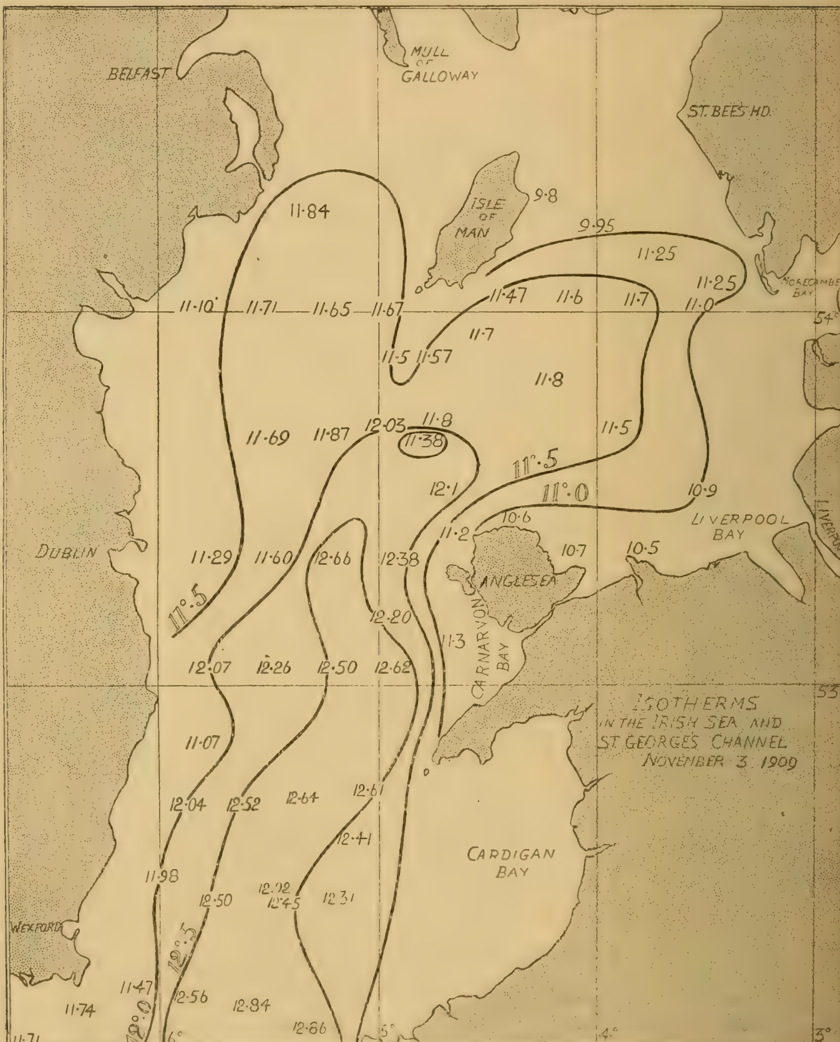


FIG. 31. Probable isotherms in the Irish Sea and St. George's Channel on November 3rd, 1909.

It is also clear that all the indications point to the main drift of water from St. George's Channel, between Isle of Man and Holyhead, and not between Isle of Man and Ireland. No doubt some water may traverse the latter part of the channel, but the directions of the isotherms appear to me to indicate that the sea immediately to the South and West of the Isle of Man is characterised by a less strong circulation than is the case nearer to the coast of North Wales.

Because of the relatively strong inflow round the

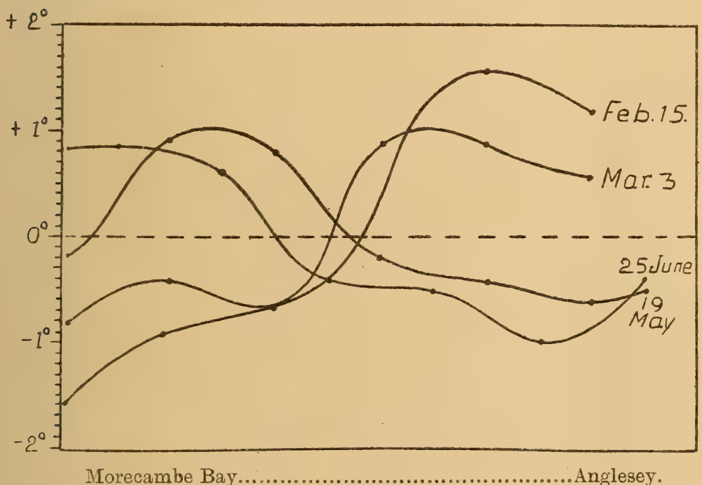


FIG. 32. Temperature gradient during certain traverses across the Irish Sea from Morecambe Bay to Pt. Lynas.

coast of Anglesey, we find that the temperature range in the sea off this part of the coast is less than that further to the North along the Cheshire and Lancashire littoral. The water in the Red Wharf Bay region is therefore colder in the summer, and warmer in the winter, than that of the inshore part of Liverpool Bay. One sees this when studying the temperature variations which may be observed while making passages from Fleetwood or Piel to Point Lynas. Fig. 32 represents the gradient on

four such passages, two of which were made about the time of the annual minimum of temperature, and two about the time when the sea temperature was rising to the maximum. The means were:—February 15, 5·4°; March 16, 5·06°; May 19, 9·4°; and June 25, 12·37°. In February and March the temperature rises on the whole during the passage from Morecambe Bay to Anglesey, but in June and May it falls. The points on the diagram represent the actual deviations from the means at each spot on the line traversed when temperature observations were made. I have drawn the curve smoothly through the actual points, since it is likely that the temperature change was a gradual and continuous one, and that the observations themselves had no significant error.

This difference in sea temperature between Anglesey and Morecambe Bay is due not only to the inflow of water round the former island, but also to the great effect of the extensive area of sandbanks in Morecambe Bay. On the 4th May, 1909, I made a series of observations of temperature in the water of the shallow gutters and pools left by the ebb-tide on the sands immediately to the North and East of Roa Island, in the Barrow Channel. The lowest temperature was 14·2°, and the highest was 17·2°. At about the same time the water in the fairway of Barrow Channel varied from 8·5° to 8·9°, and outside, in a line between the South end of Walney Island and Fleetwood similar readings were taken. At the end of July the temperature in the same place on the sands was as high as 20·5°, while midway across the mouth of Morecambe Bay it did not exceed 16°. It is quite evident that the tidal stream surging backwards and forwards over these sands must influence the temperature of the water out from the land to a very considerable degree.

Sea-Temperatures at the Light Vessels, 1908-1909, monthly means.

	Carnarvon Bay. 53°6′N. 4°45′W.	Liverpool North-West. 53°31′N. 3°31′W.	Morecambe Bay. 53°54′N. 3°31′W.	Bahama Bank. 54°20′N. 4°13′W.	Solway. 54°48′N. 3°32′W.
1908.					
January ...	8·1	5·85	4·95	6·73	4·36
February...	7·2	5·5	5·05	6·33	5·16
March	6·83	5·73	5·1	5·85	5·23
April	7·2	6·66	5·5	7·00	6·83
May	8·65	9·6	10·0	9·3	10·95
June	10·85	12·8	12·76	11·83	14·26
July	12·6	15·95	15·7	15·0	14·95
August ...	12·75	15·4	15·76	15·15	15·76
September	13·25	13·45	14·05	14·05	14·00
October ...	13·2	12·65	13·76	13·9	13·26
November	12·36	10·16	10·56	11·45	9·2
December	11·05	6·26	8·2	8·33	5·8
1909.					
January ...	8·76	6·55	5·6	7·05	4·7
February	7·5	5·8	4·36	5·73	4·36
March	7·4	5·1	3·86	5·23	3·95
April	7·7	7·23	6·73	7·33	6·36
May	9·6	10·4	9·6	9·7	10·05
June	11·16	12·6	12·26	12·26	13·9
July	12·75	14·83	14·2	13·83	15·2
August ...	14·1	15·66	15·6	15·2	15·95
September	14·26	14·6	14·0	14·45	13·9
October ...	13·0	13·15	12·3	12·86	11·55
November	11·1	9·25	8·7	9·86	7·05
December	9·43	8·9	7·45	7·55	4·86

Sea-Temperatures at the Surface at the Hydrographic Stations in 1909.

Station.	Position.	Dates.						
		25-29 Jan.	19-21 Mar.	17-19 May.	14-18 June.	26-28 July.	14-16 Sept.	1-4 Nov.
1	54°N. 3°30′W.	5·2	4·95	10·35	12·4	14·73	14·55	11·00
2	54°N. 3°47′W.	5·8	5·5	10·05	12·5	13·87	14·45	11·7
3	54°N. 4°4′W.	6·4	5·85	8·9	13·33	13·65	14·0	11·6
4	54°N. 4°20′W.	7·7	5·75	8·9	11·73	12·95	13·6	11·47
5	53°53′N 4°46′W.	8·3	6·6	8·53	10·62	12·45	12·9	11·57
6	53°43′N. 4°44′W.	8·4	6·7	8·5	10·1	12·80	13·08	11·8
7	53°33′N. 4°41′W.	8·15	6·3	8·70	10·42	13·3	13·4	12·1
8	54°4′N. 3°28′W.	5·3	5·5	9·3	12·05	15·15	14·15	11·25
9	54°9′N. 3°44′W.	5·9	5·65	9·05	12·55	14·15	14·15	11·25
10	54°13′N. 3°59′W.	6·0	5·1	8·95	12·75	13·75	13·95	9·95
11	53°56′N. 4°31′W.	*6·8	6·1	8·80	10·7	12·5	13·1	11·7
12	53°48′N. 4°13′W.	*6·1	6·8	8·83	11·60	12·65	13·6	11·8
13	53°41′N. 3°55′W.	*5·65	6·8	9·1	13·82	13·75	14·35	11·5
14	53°31′N. 3°31′W.	—	5·2	9·5	13·3	14·0	14·4	10·9
15	53°26′N. 4°5′W.	—	5·65	9·3	12·05	14·0	13·95	—

* Positions on this cruise, with respect to these three stations, were :—

Station 11, 53°54′N. ; 3°59′W.
„ 12, 53°47′N. ; 3°45′W.
„ 13, 53°39′N. ; 3°30′W.

Sea-Temperatures at Coastal Stations, monthly means, 1908-9.

Position of Station.	Piel Gas Buoy. 54°1′N. 3°12′W.	Morecambe Bay. 53°59′N. 3°6′W.	Blackpool Ground. 53°50′N. 3°5′W.	Nelson Buoy. 53°43′N. 3°12′W.	Liverpool Bar. 53°32′N. 3°17′W.	Great Ormes Head. 53°21′N. 3°53′W.	Red Wharf Bay. 53°22′N. 4°5′W.	Point Lynas. 53°26′N. 4°17′W.	Middle Mouse Island. 53°27′N. 4°26′W.	Carmel Head. 53°24′N. 4°35′W.	South Stack. 53°18′N. 4°43′W.	Bardsey Sound. 52°47′N. 4°47′W.	Patches Buoy, Cardigan Bay. 52°26′N. 4°16′W.	New Quay Head, Cardigan Bay. 52°14′N. 4°23′W.
1908.														
August ...	—	15·65	16·15	—	—	—	—	—	—	—	14·55	—	17·15	—
September	13·95	—	15·65	—	14·15	—	—	—	—	—	14·11	14·10	15·25	—
October ...	14·55	14·70	14·2	14·55	13·95	—	14·13	—	—	—	14·6	14·15	—	—
1909.														
January ...	5·45	5·35	4·35	4·55	6·15	6·85	8·40	—	—	—	8·30	8·45	7·00	—
February	4·20	4·35	*4·3*	3·75	4·85	6·72	6·35	6·40	5·95	6·95	6·95	6·90	5·85	6·35
March	4·75	4·15	3·45	3·95	3·55	3·88	5·70	5·15	5·20	5·65	6·06	6·88	5·55	6·08
April	7·75	7·22	7·48	7·75	7·25	7·00	7·65	7·76	7·55	7·73	7·85	7·80	6·75	6·85
May	8·6[illegible]	9·47	10·25	10·55	11·85	9·75	9·08	9·15	9·10	9·25	9·48	10·15	11·75	11·15
June	11·85	12·82	13·6	13·65	14·85	12·85	12·54	11·45	11·62	11·67	11·49	11·51	12·65	12·85
July	14·65	14·75	15·95	15·15	15·15	14·74	13·95	13·32	13·31	13·12	13·12	12·95	—	14·65
August ...	*16·4*	*16·9*	16·05	16·25	15·75	16·15	15·85	14·6	14·20	14·20	14·35	14·35	—	16·15
September	13·85	13·95	13·85	13·75	14·15	14·25	14·52	14·22	14·18	14·25	14·25	14·6	16·05	15·59
October ...	13·25	12·55	12·75	12·85	13·55	13·55	13·75	13·45	12·75	11·92	12·49	13·48	12·95	14·98
November	9·3	8·95	7·2	7·55	9·35	8·88	8·65	10·25	9·35	8·55	—	—	—	—
December	—	—	5·4	5·95	—	7·01	8·25	7·95	8·25	8·45	—	—	—	—

Figures in italics represent interpolated values.

NOTE ON THE FLOOKBURGH COCKLE BEDS.

By Andrew Scott, A.L.S.

The Rev. J. Fowler, Vicar of Cark-in-Cartmel, who takes a very great interest in the welfare of the Flookburgh fisherman, wrote to Mr. Muspratt a short time ago drawing his attention to the deplorable condition of the cockle beds at Flookburgh, and pointed out that for the first ten months of 1909 only 439 tons were dispatched, as against 1,647 tons in 1907 and 1,330 in 1908. On January 6th Mr. Muspratt wrote asking me to communicate with Mr. Fowler and arrange to inspect the beds at an early date. Special enquiries as to the damage likely to be caused to the beds by the black headed gulls, and whether the number of these birds have increased materially of late were to be made. The weather of January proved very unfavourable for a careful inspection of the extensive area worked by the Flookburgh men, but as this report had to be sent in some days previous to the meeting of the Scientific Sub-Committee on February 9th there was no time to wait for favourable days. Two visits were made, viz., on January 17th and January 26th. On the first date a N.W. gale accompanied by heavy rain showers had to be faced. The second visit was made during the intense frost that followed the snowstorm of January 22nd. Although the weather was unfavourable and the gulls much less numerous than they would have been under more satisfactory conditions, there was every evidence that they are very destructive to the growing cockles. On the first visit I watched a flock of about 50 birds feeding. I then examined the ground and the excreta. The freshly evacuated excreta was very plentiful considering the number of birds in the flock and proved that they had been feeding actively. Practically

the whole of the excreta of these birds was composed of pure crushed shells of one and two year old cockles. In a few cases the fragments of cockle shells were mixed with crushed shells of "Henpens" (*Tellina balthica*). Excreta consisting of pure "Henpen" shells was only observed in two instances. In the interval between the visits, a good deal of shooting had been done and it was impossible to get close to the gulls which were much more numerous than before, and were scattered in flocks all over the sands. The excreta again consisted of little else than the crushed shells of cockles. The gulls that I watched feeding simply picked the cockles directly out of the sand, but the fishermen state that they have frequently seen them tread the sand with their webbed feet with a similar effect to the use of the "Jumbo" only on a smaller scale. The birds then eat the cockles brought to the surface. The fishermen say that the adoption of a close time for gulls under the Wild Birds Protection Acts has led to a vast increase in the number of birds produced each year, they are becoming less afraid of man, and are the chief cause of the decreasing yield of cockles at Flookburgh. From the observations I made, I saw that the gulls follow the track of the "Jumbo" pretty much as they follow the plough on land and eat the cockles that remain at the surface. The Rev. J. Fowler, who has lived at Cark for 13 years, says there has been an extraordinary increase in the number of gulls in his experience. He has frequently seen many thousands of these birds feeding on the sands, and within recent years two gulleries have become established on Holker Mosses, between Cark and Haverthwaite. Dr. Jenkins in his report for the Quarter ending December, 1904, gives a chart of Morecambe Bay showing the cockle beds and the gulleries. He made a personal visit to the beds and agreed with the statements made in previous Quarterly Reports

as to the destructive action of the gulls. The chart shows three gulleries, viz., The South End of Walney Island, Cockerham and Wyresdale. Mr. Fowler informs me that he knows of three additional places, viz., Ravenglass, and the two on Holker Mosses.

If the noteworthy decrease in the value of the shell-fish industry had been limited to Flookburgh, one would have had no difficulty in coming to the conclusion that gulls were mainly responsible for it. Unfortunately, however, on comparing the money value of the shell-fish landed at the Lancashire ports during the last four years, as given in the December reports drawn up for the Committee, one finds that there has been a general decrease in the money value of the Lancashire shell-fish industry from 1908. The value of the shell-fish landed at the Lancashire ports in 1907 showed a net increase of £5,117, compared with the value in 1906. This gain was made up by an increase of £2,645 at Morecambe, and £1,558 at Cark. Southport, Fleetwood and the Lune Estuary contributed practically the remainder of the gain. The money value in 1908 showed a net decrease of £4,098. The loss of fully half of this sum occurred at Southport. Lytham, Fleetwood, Morecambe and Cark divided the remainder of the loss. In 1909 a further net decrease of £4,447 took place. Morecambe suffered to the extent of £2,158. Cark and Southport lost practically £1,382 each. Out of the nine Lancashire ports only two showed any increase over 1908. Fleetwood improved by £917 and Barrow District by £99. The general decrease in the money value of the Lancashire shell-fish industry especially during 1909 is not due entirely to the destruction brought about by gulls.

All shell-fish beds have many natural enemies. Plaice and flounders feed vigorously upon small mussels and cockles. We generally find when flat fish are plentiful

near the shore during the summer and autumn, that they have been attracted by the abundance of small shell-fish. The common starfish or crossfish soon destroy a mussel bed once they settle upon it. Gulls, as we know, help very considerably to destroy young cockles. They have doubtless done so from very early days, and if unchecked can cause great local destruction.

The chief cause of the fluctuation of the fisheries for shell-fish along the Lancashire coast is due to natural influences. Some marine animals are more susceptible than others to the climatic changes that are always going on around us, and naturally suffer from a sudden rise or fall of the temperature of the sea. The eggs produced by a spawning cockle are fewer in number than is the case with the mussel, and spawning takes place in the early spring. The spat from the bed of cockles may, therefore, be completely destroyed by the sea water becoming suddenly cooled as it flows over the surface of very cold sands. A whole year will elapse before another production of spat will take place. An intense frost will kill large numbers of cockles wherever its influence is felt. In the winter of 1894-5 the whole of the Lancashire coast line was covered with ice-floes for a considerable time and many hundreds of tons of dead cockles were washed up by the first gale after the frost had disappeared. The extreme cold of that winter had a marked effect on the fishery at Flookburgh and the total quantity of shell-fish sent off during 1895 was only 743 tons. The beds may become sanded up by heavy seas washing over them, or through the shifting of the numerous channels, and the shell-fish are smothered.

Over-fishing may also occasionally take place, and it is a well known fact that some beds take longer than others to produce marketable shell-fish once they have been depleted. The fisherman to his own advantage ought to

take great care of the undersized shell-fish, because after all these are the hope for the future. The small cockles for instance that pass through the riddle ought not to be left in heaps to shift for themselves. They ought to be spread out a little and lightly forced back into the sand. If the heaps are simply left untouched they are exposed to the attacks of the gulls, the frost of winter, or the warm sun of the summer, and none of these influences are good for the welfare of a cockle bed. A female cockle begins to produce spat when it is between two and three years of age and it is at this period that it becomes marketable. It therefore follows that if large quantities of cockles which just fail to pass through the legal riddle are taken away between the autumn of one year and the spring of the next, the repopulation of a bed by a fresh supply of young will be greatly retarded.

The present condition of the cockle industry at Flookburgh is unsatisfactory and young cockles are very scarce. One bag of marketable cockles per man each tide is all that is being obtained. The suggestions given by Dr. Jenkins in his Quarterly Reports ending December, 1904 and 1905, afford the best solutions to counteract the present decrease in the population of the Flookburgh beds. They are (*a*) Advice to the fishermen not to sell on commission; (*b*) The exemption of gulls from the provision of "The Wild Birds Protection Act."; (*c*) Restriction of the use of the "Jumbo" to a minimum, or even its total abolition. A reduction in the number of gulls could easily be brought about by destroying the eggs in the nesting season. I do not think the total abolition of the "Jumbo" would be regarded as a hardship by the fishermen as some of them that I met at Flookburgh voluntarily suggested it, stating that many cockles brought up to the surface by its use are not marketable. Care should also be taken to spread the

small cockles that pass through the riddle, and press them into the sand. If a supply of small cockles can be secured in the spring an attempt should be made to restock parts of the Flookburgh area.

The following table gives the amount, in tons, of shell-fish sent off by rail from Cark Station during the last twenty-eight years. The figures, with the exception of those for 1908 and 1909, have been taken from the notes by Mr. W. R. Nash, " Cartmel District Weather and Farming Notes." The Lancashire Sea Fisheries Committee was not in existence during the first eight years of this period and in the twenty years that have elapsed since its institution the quantity of shell-fish sent away from Cark Station each year has only once been less than the quantity dispatched in 1886.

Year.	Tons.	Year.	Tons.
1882	2,827	1896	930
1883	2,665	1897	2,011
1884	1,177	1898	1,797
1885	861	1899	1,286
1886	662	1900	1,059
1887	1,040	1901	1,250
1888	1,616	1902	1,232
1889	2,488	1903	885
1890	3,161	1904	770
1891	2,749	1905	394
1892	1,684	1906	1,009
1893	1,336	1907	1,647
1894	1,218	1908	1,374
1895	743	1909	718

The majority of the cockles dispatched from Flookburgh find their way into the cotton districts of Lancashire, and when any disturbance takes place in the cotton trade, either through scarcity of work or lock-outs, it is said

that the demand for cockles falls off. Mr. W. R. Nash in his monthly notes for 1908 on the sand fishery at Flookburgh, makes the following remarks: "Owing to the impoverished condition of so many cotton workers and traders, and others dependent upon them for a living, the demand for cockles has fallen off very much, and during several weeks double the quantity actually sent could have been supplied had there been any demand." The quantity of shell-fish sent away from Cark in 1908 shows a reduction of 273 tons when compared with 1907. Some of this reduction at any rate was probably due to the depression in the cotton trade in 1908.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART III.

By W. A. Herdman, F.R.S., Andrew Scott, A.L.S., and W. J. Dakin, M.Sc.

[Explanatory Note.—The work was carried on in 1909 very much on the same lines as in the two previous years. The same localities were fished, and the same nets were used, with the addition of a few improved forms to be discussed below. Mr. W. Riddell again gave most efficient help in the operations at sea, and Mr. Scott and I have divided the work of preparing this report in exactly the manner that was stated in last year's Introductory Note. Mr. W. J. Dakin (now Demonstrator of Zoology in the University of Belfast), while working at Port Erin as "1851" Exhibitioner in Zoology of the University of Liverpool, in April, 1909, took entire charge of our hydrographic observations at sea, and of the subsequent working up of these in the laboratory. When I had to return to Liverpool, in May, Mr. Dakin continued both the planktonic and the hydrographic observations with some of our nets and instruments, but according to a modified scheme, taking samples twice a week during the greater part of the summer. As this portion of the work, although planned under my direction, was carried out wholly by Mr. Dakin, Mr. Scott and I invited him to join us as part-author of this report, and consequently the section on hydrographic results has been drawn up by Mr. Dakin, and he has also helped me in some of the other sections.

We are indebted to Mr. Chadwick for much help at the Port Erin Biological Station; to Mr. Riddell for his assistance in the Liverpool Laboratory in analysing, comparing and discussing the results of the many hauls taken during the year; and to Miss Lewis for the numerous statistical lists, tables of occurrence and curves which she has drawn up. Mr. Riddell and Miss Lewis have been most helpful during the writing out of this report, and have saved me much time by preparing the material for me to consider and discuss.—W. A. Herdman.]

INTRODUCTION.

We shall first under this heading give an account of how the work was carried out in 1909. Then will follow a section on the hydrographic conditions off Port Erin. Finally, the planktonic results will be discussed in detail.

The Material Available.

The collections made this year have been more numerous than in either of the previous years, but for the most part fall into the same series of samples, and are therefore directly comparable with those of '07 and '08. The total number of samples now examined in this intensive study of a small marine area is nearly 2,000, made up as follows:—

Year.	At Sea, from Yacht. Spring.	Autumn.	In Bay throughout Year.	Mr. Dakin's hauls.	Totals.
1907	218	279	138	—	635
1908	156	242	157	—	555
1909	329	147	231	49	756
Totals	703	668	526	+ 49	1,946

It will be seen, moreover, that each of the three years, and each of the three vertical columns, is represented by a substantial number of gatherings, and that these numbers are fairly equal, lying as all six do between 526 and 756.

Of the total number (1,946) of samples, a small proportion (73) were taken with larger nets—the shear, the Yngel and the large Nansen—which cannot be regarded as comparable with the rest. The shear appears to catch about 15 times as much as an ordinary small tow-net, and the large Nansen (100 cm. in diameter of mouth) about 10 times as much. The Yngel has at least the same catching power as the shear net. Of the remainder, 511 are hauls taken with vertical closing nets (Hensen and Nansen), not very different in size and catching power from the ordinary tow-nets of 14½ inches diameter of ring, with which the other 1,362 samples were obtained. Of course individual nets differed somewhat in their catches according to the shape and make, but when seven of them (" Hensen," " Nansen," " Weight," " Otter," " Coarse," " New," and " Old ") were used simultaneously day after day, we believe a useful roughly approximate idea of the proportional variations in the plankton can be obtained by averaging the hauls so as to get a single figure per net for each locality (see below, pp. 345-349).

Outline of the Year's Work.

Throughout the year, from January 1st, 1909, to December 29th, Mr. Chadwick took " official " gatherings across Port Erin Bay, generally twice a week, and sometimes more frequently. The S.Y. " Ladybird " (fig 1) was fitted out for the season towards the end of March, and her first plankton trip was on March 27th. From that

time to April 26th she was constantly engaged in this work, and obtained 329 collections on 23 working days. During that period we have the yacht gatherings taken at various stations (see fig. 2) out at sea (up to 12 miles N.W. of Bradda Head), and also the "official" gatherings taken across the Bay. After April, Mr. Dakin, from a

FIG. 1.—S.Y. "Ladybird" on a Plankton cruise at Easter, 1908. From a photo by Edwin Thompson.

small sail-boat, continued the work at sea in a modified form from May 3rd to July 1st inclusive. The "Ladybird" took collections again almost daily from August 3rd to 11th (147 gatherings in 8 working days). After that date we have only the official gatherings in the Bay up to the end of the year.

Methods and Equipment.

The methods of work were practically the same as in the previous two years. It may be useful to repeat here the same little map that was used last year in order to show the localities at which the gatherings were taken. The nets used throughout the three years have been:—Two closing vertical nets, the Nansen and the Petersen-

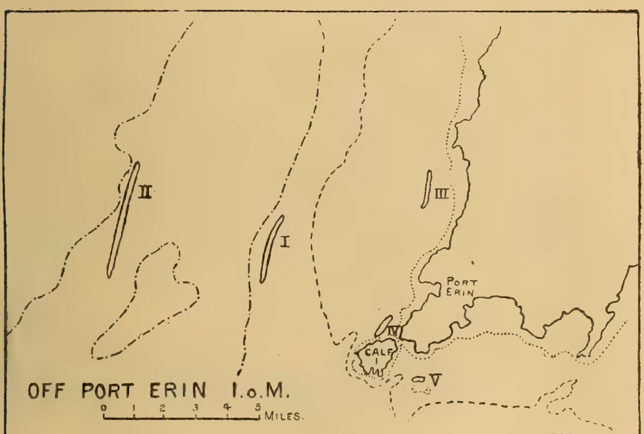


Fig. 2.—The Offshore Plankton Stations.

Hensen, a weighted and two surface, open, horizontal tow-nets, all made of No. 20 bolting silk; and, in addition, some coarser silk tow-nets (Nos. 3, 6 and 9 silk) and the larger-meshed shear-net and Yngel trawl.

In the equipment for the present year, while keeping the older nets for the sake of continuity and comparison, some new ones were added, viz., a large Nansen, 100 cm. in diameter of No. 3 silk; and a series of "funnel" nets (fig. 3) which will be referred to again below, one of them

being attached to a small otter-board worked from the ship's side far forward for comparison with the others at the stern.

The yacht was furnished with a small "Lucas" sounding machine, having 400 faths. of steel piano wire, which has been found to be of service in giving rapid and

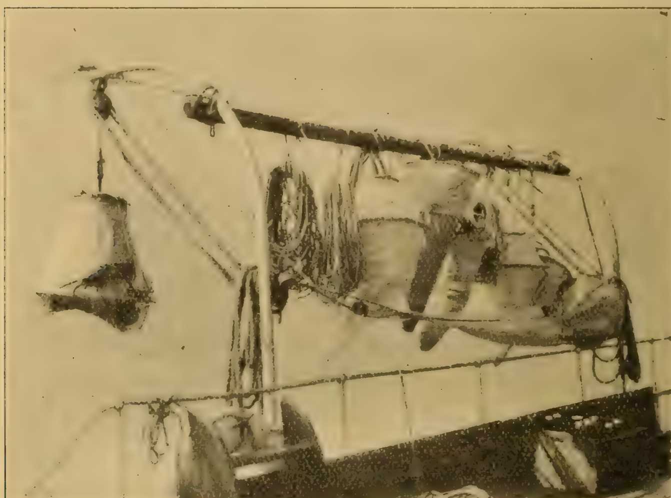


FIG. 3.—"Hensen," "Nansen," "Funnel" and "Open" Plankton nets on "Ladybird." From a photo by Edwin Thompson.

accurate soundings, and for the water-bottle and thermometer in the hydrographic work, and also on occasions for taking vertical hauls with the Nansen net (fig. 4).

We have also added to the equipment for the hydrographic work an Ekman Water-bottle provided with Richter's thermometers and, for occasional work, the lighter Buchanan-Richard (or "Monaco") Water-bottle (fig. 5) as used on the Prince of Monaco's scientific yacht "Princesse Alice."

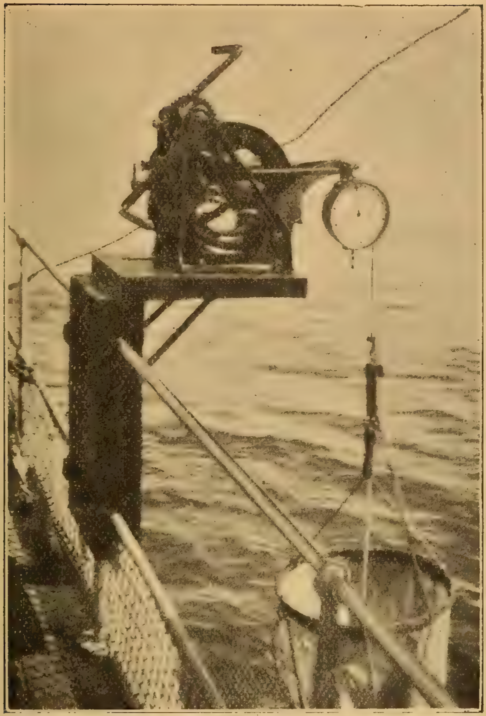


FIG. 4.—Lucas Sounding Machine, as used with Nansen vertical closing net on "Ladybird."

FIG. 5.—The "Monaco" Water-bottle; on the right descending open, on the left ascending closed. The messenger (on the line) which strikes the lever, raises the pin and so allows the brass bottle to reverse and close itself, is seen in each case at the top of the figure. The two projecting sockets are for the reception of a thermometer which reverses with the water-bottle.

HYDROGRAPHIC CONDITIONS OFF PORT ERIN IN APRIL TO JUNE (Drawn up by W. J. Dakin).

This is an account of the hydrographical observations made in conjunction with the plankton work carried on by Professor Herdman in April, and of those made in May and June whilst taking plankton samples myself. The former, which are in greater detail, were carried out on the steam yacht "Ladybird," the latter on a small sailing boat. I have dealt chiefly with the temperature and salinity of the water, but some oxygen determinations were also made during April. In order to discuss differences in catches of nets at different times and places, it is necessary to know the prevailing conditions of environment affecting the plankton, at those places. The observations are confined practically to two stations (I and III). They have, however, been very numerous and probably such an intensive study at stations isolated from the larger land masses is of rare occurrence.

Much of the German quantitative plankton research has been carried out on the Baltic Sea, where the hydrographic conditions are most varied and interesting, but may, I think, lead to rather one-sided views. It is quite obvious, for example, that if the surface salinity is only 18 °/$_{oo}$ and that of the bottom water is 26 °/$_{oo}$ it will make a marked difference in the plankton. It seems natural under such circumstances to correlate changes in plankton with changes in the hydrographical conditions.

These great changes, however, may completely mask other smaller variations which exist in places where the salinities and temperatures are approximately alike. It is under these latter conditions that plankton problems must be attacked in the Irish Sea, which is, as far as

affects the plankton, practically a homothermic and homosaline water mass.

Temperatures in April.

The surface temperatures have been taken with Richter thermometers divided into $\frac{1}{10}$° C. and provided with Charlottenberg certificates. The correction has been applied in all cases. The deeper temperatures have been taken with a Richter reversing thermometer attached to an Ekman Water-bottle. Two thermometers should be used, or temperatures be taken twice at the same depth (and not in succession), in order to check the readings, since the best reversing thermometers may at times prove fickle. For comparison there exist at present only some records taken in recent years by Mr. Johnstone on board the "James Fletcher" at two stations not far from the Isle of Man, and a few taken by Mr. Drew on the "Ladybird" during the summer of '08 at our two Stats., I and III, lying 5 miles and 2 to 3 miles outside of Bradda Head, respectively.

Stat. I. 5 miles N.W. Bradda—Corrected temperatures.

Depth	April.						
	5	6	7	8	9	13	14
0 fathoms	7·10	7·22	7·52	8·15	7·92	7·42	7·62
5 ,,	—	—	—	7·62	7·27	—	—
10 ,,	7·82?	7·62?	7·12	7·18	7·12	—	7·43
15 ,,	—	—	—	—	—	7·23	—
20 ,,	7·82?	7·87?	7·22	7·19	7·17	—	7·42
25 ,,	—	—	—	—	—	7·22	7·37

	15	19	21	23	24	26
0 fathoms............	7·77	7·62	7·57	7·64	7·72	8·12
5 ,, ...	7·57	7·52	—	—	—	—
10 ,, ...	7·39	7·48	7·52	—	7·65	7·78
15 ,, ...	7·35	7·48	—	—	7·67	7·78
20 ,, ...	—	7·48	7·30	—	7·67	7·76
25 ,, ...	7·32	—	—	—	—	—

Stat. III. 3 miles N.N.W. Bradda--Corrected temperatures.

Depth.	April. 5	6	9	13	14	15
0 fathoms............	6·37	6·92	9·52	7·42	7·62	7·84
5 ,, ...	—	—	—	—	7·47	7·67
10 ,, ...	7·02 ?	7·47 ?	6·82	—	—	—
15 ,, ...	7·10 ?	7·58 ?	—	7·17	7·37	7·37
20 ,, ...	—	—	7·10	—	—	—

	17	19	23	24	26
0 fathoms.........	7·72	7·80	7·92	7·92	8·17
5 ,, ...	7·64	7·69	—	7·70	8·07
10 ,, ...	—	—	—	7·67	7·82
15 ,, ...	7·52	7·47	—	7·65	7·75
20 ,, ...	—	—	—	—	—

It will be seen that at both stations there has been a steady and slow increase in the temperature throughout the month, with one exception, on the 8th and 9th, when an abnormal rise was noted, which fell during the following days to the normal. The curves are, however, not much broken up—that is, the minor temperature variations referred to by Johnstone* have not been of great magnitude, nor of frequent occurrence. This is probably due to the isolated position of the Isle of Man and the freedom from such disturbances as are caused by a rising tide passing over heated sandbanks.

It will be seen that the change noted on the 8th and 9th is of far greater magnitude at Stat. III, near the land, than at the 5-mile station, and in fact the coldest and warmest surface temperatures were observed at the in-shore station. During January, February and, perhaps, March the lowest temperatures will be at Stat. III, whilst in April and the following months the temperature will be on the average slightly higher (as the tables for April indicate), but a succession of abnormally

* Lancashire Sea-Fisheries Laboratory Report, p. 73, 1908.

warm days in February or March would quickly affect the water at Stat. III, and similarly a sudden fall in April, reversing these conditions. The great rise that has been referred to above and also its effect on the vertical distribution of temperatures can be traced quite easily to the weather conditions. After a prolonged period of cold weather with a steady thermometer, there followed three or four abnormally fine and hot days (the temperature of the air only reached that attained at that time on about five days between then and July 16th). From the 6th to the 9th the sea was calm, there was practically no wind, and continuous sunshine prevailed during the day. The result was a very considerable heating of surface water, the deeper water, however, remaining unaffected. The minor increase on the 15th was due to a similar though less marked cause.

Vertical Distribution of Temperature.

These records, though taken in shallow waters, with the exception of one series made in water of over 60 faths., are not without interest, and seem to support the view that the Irish Sea is practically a homothermic water mass, though Johnstone states that in 60 cases the bottom water was coldest, in three cases was warmest, and in three cases was the same as the surface.

My records are as follows:—From April 8th onwards 10 series were taken at Stat. I, 9 series at Stat. III, and 1 at Stat. A in deep water. In every case the bottom water was colder than the surface water, but by very small amounts. In all cases but four the difference between surface and bottom water was less than half a degree. These four cases occurred on the 8th and 9th of April. The differences between surface and bottom were 0·96° C., 0·75° C., 2·42° C., and 0·53° C. The greatest of these differences is less than those observed by Drew on the

"Ladybird" in the summer of '08, and all may be explained by the abnormal heating of the surface water, as can be readily seen from the curves. If the 10 fath. temperature be compared in those four series with the bottom (20 faths. in three cases and 60 faths. in the other) the differences are only 0·01° C., 0·05° C., 0·28° C., and 0·32° C. respectively. Thus, where the difference was so great as 2·42° C. between the surface and the bottom, a difference of 2·14° C. existed between the surface water and that at 10 faths., plainly due to the heating effects of the sun. I find, therefore, no great difference between surface and bottom water, always less than half a degree except on abnormal occasions, and a difference of over 2° C. can be produced solely by the action of the sun's rays on the surface water. Such small differences can scarcely be used as evidence for the inflow of colder currents from without, and I imagine will exercise no perceptible influence upon the vertical distribution of planktonic organisms.

Salinities in April.

The samples of sea-water examined were taken with the Ekman Water-bottle, at the same time as the temperatures. The remarks made with regard to the frequency of the determinations of temperature apply, therefore, with equal force here, though the temperatures will naturally vary and be affected by weather conditions to a greater extent than the salinity. The salinities have been determined by titrations of chlorine by Mohr's method, using the Knudsen apparatus and referring the results to standard sea-water. The salinities, etc., were then calculated by means of Knudsen's hydrographic tables. T° is the temperature (Centigrade) of the water in situ, Cl ‰ is the amount of chlorine per 1,000 parts of water, and S ‰ is the salinity.

Stat. I. 5 miles N.W. Bradda.

Date.	Depth in fathoms.	T°	Cl ‰	S ‰
April 5...	0	7·10	18·98	34·29
,, 5...	10	—	18·95	34·23
,, 5...	20	—	18·97	34·27
,, 6...	0	7·22	19·00	34·33
,, 6...	10	—	18·98	34·29
,, 7...	0	7·52	18·94	34·22
,, 8...	0	8·15	18·96	34·25
,, 9...	0	7·92	18·92	34·18
,, 9...	10	7·12	18·93	34·20
,, 9...	20	7·17	18·98	34·29
,, 13...	0	7·42	18·86	34·07
,, 13...	15	7·23	18·90	34·14
,, 13...	25	7·22	18·90	34·14
,, 14...	0	7·62	18·92	34·18
,, 14...	15	7·43	18·89	34·13
,, 14...	30	7·37	18·90	34·14
,, 15...	0	7·77	18·89	34·13
,, 15...	10	7·39	18·91	34·16
,, 15...	30	7·32	18·92	34·18
,, 19...	0	7·62	18·88	34·11
,, 19...	10	7·48	18·91	34·16
,, 19...	15	7·48	18·92	34·18
,, 19...	20	7·48	18·91	34·16
,, 21...	0	7·57	18·84	34·04
,, 21...	10	7·52	18·85	34·05
,, 21...	20	7·30	18·93	34·20
,, 23...	0	7·64	18·91	34·16
,, 23	10	—	18·91	34·16
,, 23...	15	—	18·91	34·16
,, 23...	20	—	18·90	34·14
,, 24...	0	7·72	18·91	34·16
,, 24...	10	7·65	18·91	34·16
,, 24...	15	7·67	18·92	34·18
,, 24...	20	7·67	18·91	34·16
,, 26...	0	8·12	18·91	34·16
,, 26...	10	7·78	18·92	34·18
,, 26...	15	7·78	18·93	34·20
,, 26...	20	7·76	18·92	34·18

Stat. III. 2 to 3 miles outside Bradda.

Date.	Depth in fathoms.	T°	Cl °/oo	S °/oo
April 5...	0	6·37	18·99	34·31
,, 5...	10	—	18·96	34·25
,, 6...	0	6·92	18·91	34·16
,, 6...	10	—	18·93	34·20
,, 9...	0	9·52	18·87	34·09
,, 13...	0	7·42	18·83	34·02
,, 13...	15	7·17	18·89	34·13
,, 14...	0	7·62	18·86	34·07
,, 14...	15	7·37	18·87	34·09
,, 15...	0	7·84	18·91	34·16
,, 15...	5	7·67	18·87	34·09
,, 15...	15	7·37	18·89	34·13
,, 16...	0	7·8	18·92	34·18
,, 16...	20	—	18·92	34·18
,, 19...	0	7·80	18·90	34·14
,, 19...	5	7·69	18·86	34·07
,, 19...	15	7·47	18·90	34·14
,, 23...	0	7·92	18·93	34·20
,, 23...	5	—	18·91	34·16
,, 23...	10	—	18·91	34·16
,, 23...	15	—	18·92	34·18

Stat. A. 13 miles N.W. Bradda.

Date.	Depth in fathoms.	T°	Cl °/oo	S °/oo
April 7...	0	—	18·90	34·14
,, 7...	20	—	18·88	34·11
,, 7...	30	—	18·93	34·20
,, 7...	40	—	19·03	34·38
,, 7...	50	—	19·04	34·40
,, 7...	60	—	19·03	34·38
,, 8...	0	7·85	18·85	34·05
,, 8...	5	7·04	18·83	34·02
,, 8...	10	7·00	18·85	34·05
,, 8...	20	7·07	18·86	34·07
,, 8...	30	7·17	18·91	34·16
,, 8...	40	7·20	18·98	34·29
,, 8...	60	7·32	19·03	34·38

On the whole, these results will be seen to agree with those of Bassett,* which have been carried out over a more extended area. In 14 cases out of 21 series the difference between the surface and bottom is 0·05 ‰ or less, and since the experimental error may be 0·02 ‰, it will be seen that the actual difference between surface and bottom water is but small. In 8 cases it is only 0·02 ‰ or less. The greatest differences, as might be expected, are at the deep Stat. A in mid-channel, and are 0·24 ‰ and 0·33 ‰ respectively. In seven cases the surface is more salt than the bottom, in eleven cases less salt, and in three cases the same, though, as before mentioned, where the difference is only 0·02 ‰ it is too small to allow any deduction to be made. The salinities are on the whole high, but agree with Bassett's figures for the Gulf Stream water at his Stats. 5, 6 and 7 (spring '08, and for the May observations '09). One might infer from this that Port Erin was one of the places nearing the northern limit of this current to the West of the Isle of Man, since two samples of water which came from a place North of Peel in the northern tide were very different from any taken off Port Erin. The salinity was only 33·73 ‰. I do not think that the small differences, either in vertical distribution or from day to day throughout the month, would cause any great changes in the distribution of the plankton, but a sudden lowering of the surface salinity by heavy rain, which would affect the plankton of the upper layers only, might cause a descent. The influence of light and the alternation of day and night will probably produce far greater changes.† With regard to temperatures, a prolonged period of cold weather will

* *Lancash. Sea-Fisheries Labor. Report for* 1908, p. 44.

† In a series of tow-nettings taken at intervals of three hours during 24 hours at Port Erin a great difference is noticed between the surface catches taken at night and those during the day.

probably keep back certain forms, and the steady rise throughout April may influence these organisms.

Oxygen Determinations.

In these first oxygen observations for the Irish Sea, the method employed was that of von Winkler, which was used by Natterer in his work on the "Pola" expedition.

A number of bottles with well fitting glass stoppers, and holding about 275 c.c., had the volume accurately determined by weighing bottle and stopper, at first dry and then filled with distilled water, the stopper being placed in so that no air bubbles were by any chance included. The glass stoppers must have no hollows underneath where air bubbles might possibly collect. The water was collected as for salinity samples by the Ekman Reversing Water-bottle, but a piece of indiarubber tubing was fixed to the tap on the bottle and the end let down to the bottom of the glass bottle, so that the water ran in when the tap was opened without splashing or enclosing air bubbles. The procedure on the yacht was as follows: A bottle was completely filled with the sea-water to be examined. By means of pipettes with long narrow stems, first 2 c.c. of concentrated solution of NaHO (36 gr. pure caustic soda in 100 c.c. of distilled H_2O, to which 10 gr. of potassium iodide are added) and then 1 c.c. of manganous chloride solution (40 gr. $MnCl_2 4H_2O$ in 100 c.c. dist. water) were introduced carefully, so that they remained at the bottom of the bottle. The stopper was then inserted, causing some sea-water to overflow, and the bottle well shaken and brought back to shore for further treatment in the laboratory. The precipitate was allowed to settle and then 2 c.c. or more fuming hydrochloric acid were added, which dissolved it, the reaction setting free a quantity of iodine, equivalent to the oxygen

combined in the precipitate, which was the quantity formerly in the sea-water of the sample. This solution of iodine was now titrated against standard sodium thiosulphate solution, using starch solution as indicator. It is very important to test all the reagents first; addition of the hydrochloric acid to the caustic soda solution containing potassium iodide must cause no liberation of iodine.

The number of samples analysed was thirty-one. The accuracy of the analysis, however, was not like that for chlorine. For the surface water the results were 6·5, 6·82, 6·68, 6·8, 6·8, 6·8, 6·6, 6·6, 6·76, 6·76, 6·4, 6·57, 6·8 c.c. per litre of water, and for water from twenty fathoms 6·30, 6·30, 6·60, 6·30, 6·30, 6·60, 6·73, 6·3, 6·3, 6·36 c.c.‰ in all cases less than the figures for the surface water at the same station. No particular changes were noticed during the month. These figures correspond with those of Niels Bjerrum for Baltic waters in '03-'04, which also show a general decrease of oxygen with increase in depth.

TEMPERATURE AND SALINITIES DURING MAY AND JUNE.

These observations are given separately from the April results since they were made at a different station (which, however, corresponds fairly well with Professor Herdman's Stat. III of the "Ladybird" observations), 2-3 miles out from Port Erin breakwater well outside the "Bowlane Tide" running down the Manx coast North of Port Erin. Like the April observations, they were made in conjunction with plankton catches (quantitative), and twice a week, on Mondays and Thursdays, if weather permitted. A sailing boat was used, the water for salinities was taken by means of the Monaco Water-bottle, and the surface temperatures with the usual Richter thermometer.

The particulars of the plankton catches are given elsewhere in this report.

Temperatures.

May 3...	8·075°C.	May 28...	9·57°C.	June 19...	10·15°C.
,, 10...	8·95	June 1...	10·45	,, 22...	11·65
,, 13...	8·70	,, 4...	10·84	,, 25...	11·15
,, 17...	8·87	,, 7...	10·09	,, 28...	11·12
,, 21...	9·20	,, 12...	10·05	July 1...	12·7
,, 24...	10·05				

On the whole, the same rise of temperature with irregular variations, as seen in April, is continued.

Salinities.

The samples were all surface water with one or two exceptions, since there appeared to be practically no difference between surface and deep water at this depth (20 faths.).

Date.	Cl °/oo		S °/oo	
	Surface.	Deep.	Surface.	Deep.
May 13............	18·886	18·886	34·11	34·11
,, 21............	18·886	18·916	34·11	34·16
,, 24............	18·886	—	34·11	—
,, 28............	18·930	—	34·20	—
June 1............	18·900	—	34·14	—
,, 4............	18·905	—	34·145	—
,, 7............	18·920	—	34·18	—
,, 12............	18·89	—	34·13	—
,, 14............	18.90	—	34·14	—
,, 19............	18·90	—	34·14	—
,, 22............	18·87	—	34·09	—
,, 28............	18·88	18·94	34·11	34·22
July 1............	18·93	—	34·20	—

The salinities show very little fluctuation throughout the two months. The small variations can scarcely be correlated with weather conditions at Port Erin, except

that the lowest observation, that of June 22nd, occurred after rain. Since, however, the water from which the samples were taken had moved from some other district, it is quite obvious that variations might be determined by weather conditions elsewhere. There does not appear to have been any particular change in either temperature or salinity conditions accompanying the sudden disappearance of the Diatoms between May 21st and 28th. The differences between surface and bottom salinity on the three occasions when samples were taken are 0·00, 0·05 and 0·11 respectively.

PLANKTONIC RESULTS.

Under this heading we shall consider the plankton of Port Erin Bay and that of the open sea outside, the distribution of the more important groups, such as Diatoms and Copepoda, and of selected genera of these and other groups, the proportions of Oceanic and Neritic species in our fauna, the relation of the plankton to sunlight and its distribution in depth, the plankton as the food-supply of the sea, and finally shall discuss the results obtained by different types of net.

Plankton of Port Erin Bay.

Our aim has been to obtain tow-net gatherings taken across Port Erin Bay on at least two days in each week throughout the year—both fine (No. 20 silk) and coarse (No. 9) nets being used on each occasion, thus giving four gatherings in each week. Mr. Chadwick (by whom most of these "Bay" gatherings were taken) has carried out our intentions so well that we have in all 231 samples, and these represent every week in the year except the second week in January, a time of continuously bad

weather. The lowest records for any month are 14 samples in May, in July and in October, and the highest are 32 in February and 33 in March. The average per month is thus nearly 20 hauls.

The coarse and the fine net obtained very different samples, both quantitatively and qualitatively. For example, as a rule the coarse net caught more adult Copepods, and the fine net more of the Nauplii. Consequently, by adding the two hauls together we get what may be regarded as a representative sample of the plankton obtainable in one traverse of the bay. In January there were 11 hauls of the coarse net ranging from 1 to 4 c.c. in quantity, and 11 hauls of the fine net ranging from 0·1 to 1·4 c.c.; and if each pair of hauls be treated as one, the range for the month is 1·2 to 5·4 c.c., and the average double-catch is 2·2 c.c. In the following table the numbers of the Diatoms and other leading groups of organisms have been treated in a similar manner:—

	Double hauls.	Average Catch.	Diatoms.	Dinoflagellates.	Copepoda.	Copepod Nauplii.
Jan.	11	2·2	12,062	486	5,608	1,766
Feb.	16	1·76	23,998	178	1,708	658
Mar.	16	2·5	77,423	273	1,168	944
Apr	8	14·08	1,961,333	8,171	1,269	4,498
May	7	24·07	1,166,537	30,957	7,701	18,141
June	9	22·9	2,612,156	25,343	10,644	20,867
July	7	10·05	153,616	9,393	16,624	23,969
Aug.	7	6·84	8,319	3,440	20,078	14,893
Sept.	7	12·15	574,571	814	14,442	19,786
Oct.	7	5·97	27,914	289	28,935	15,879
Nov.	8	3·73	79,244	3.099	7,190	4,778
Dec.	9	4·0	37,626	2,133	8,258	4,153

This shows that the maximum catch, so far as volume is concerned, was in May; that the Diatoms have an extended maximum from April to June, with its climax at the end; that the Dinoflagellates are most

abundant in May and June, and especially in May; that the adult Copepoda go on increasing till August, and, after a drop in September, attain their highest point in October, while the Copepod Nauplii, as might be expected, precede the adults with a peak in June and July, and another in September.

If we compare this record with those of former years, it will be seen that in the important period of March, April and May the present year is closely similar to '08, and very different from '07; in June, July and August it is intermediate between '07 and '08; in September it shows an increase over the two previous years; and finally, in October-December it is very similar to '08.

The diagram (fig. 6), in addition to the columns indicating monthly averages for the three years separately, shows, in the outer clear areas to the left, an average for the three years taken together in each month, and in the black areas on the right the averages for the two years '08 and '09.

The record suggests the idea that '07 was an abnormal year. The rises in alternate months (April, June, August and October) seem unnatural, or at least unusual. The two last years ('08 and '09) agree very closely, except in June, when '09 showed far more plankton than '08. If we take a median position between these two, and connect the tops of the '08 columns by one line, and of the '09 columns by another, the resulting curves show a spring maximum culminating in May, sinking to its lowest in August and then rising again to a smaller maximum in September. This, we think, so far as our evidence goes, is probably the usual form of the annual plankton curve for Port Erin Bay, and it may be seen in the black columns (averages of '08 and '09 taken together) of the diagram (fig. 6).

The spring phyto-plankton maximum in '09 does not show any great abundance of an unusual organism, such as the immense swarm of *Thalassiosira nordenskioldii* that invaded the Irish Sea in '07.

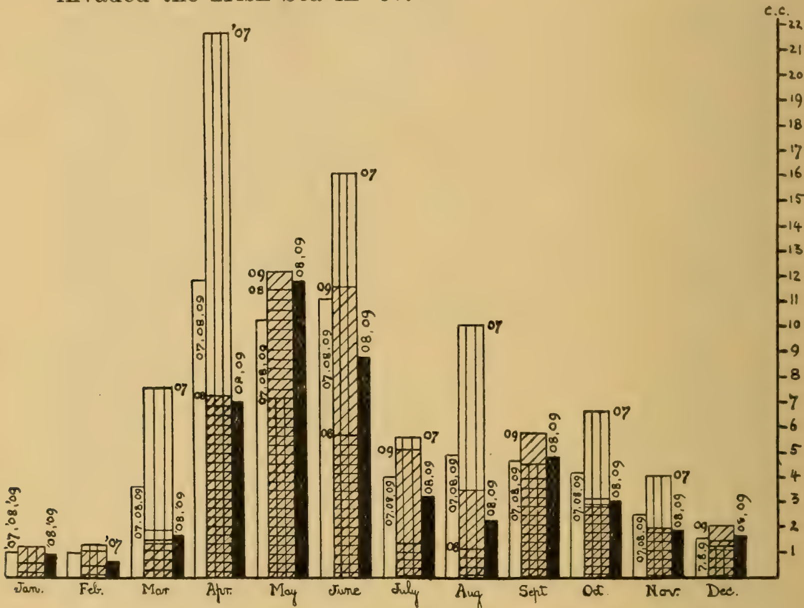


FIG. 6.—Diagram of average haul of Plankton per month in the three years, separately and combined.

There was a decided second Diatom maximum this year between September 21st and the end of the month, very much as in '07. It gradually died away in September and October, and then the usual winter species of *Biddulphia* and *Coscinodiscus* made their appearance in November.

PLANKTON OUTSIDE THE BAY.

Looking at the plankton outside the bay, as shown in the March and April gatherings from the yacht at Stat. III, with the fine surface net, and continued by Mr. Dakin's hauls in much the same locality, with the

same net, through May and June to July 1st, and then by the yacht's hauls again in August, we find the following results:—

There is a well-marked, but possibly exceptional, early Copepod maximum of short duration from April 1st to 5th. This reaches in a haul 3,000 nauplii, 1,600 juveniles and 955 adults, is apparently due to a swarm of *Oithona,* and is actually earlier than the phyto-plankton increase which usually starts and dominates the vernal maximum.

The Copepoda are more abundant in the surface nets than in the Nansen nets hauled at from 20 to 10 faths. in the earlier part of April (March 27th to April 8th), but the reverse is the case in the later part of the month (April 13th to 26th). This is not incompatible, however, with a general correspondence between the surface and the deeper hauls, the two rising or falling more or less together.

There is a marked decrease of Copepoda (as well as of the phyto-plankton) during the few days preceding April 9th, a period of relatively hot and very fine weather for the time of year. The sea-temperature falls again between the 9th and the 13th, and at that period the Diatom and Dinoflagellate maxima begin.

In August, when, compared with April, the total catch is very small (0·2 c.c., say, as against 4 c.c.), and the Diatoms are at their minimum, the Copepoda are fairly numerous, ranging up to about a thousand adults and five thousand nauplii in a haul.

The vertical hauls with the Nansen net show the same *Oithona* increase on April 1st to 5th, and also an even greater increase of Copepoda a few days later on April 14th to 23rd. The latter reaches a height of 5,396, of which 5,000 are *Oithona.* We are inclined, however,

to regard these two peaks as unusual, and if they be removed the Copepod curve shows a gradual rise during May and June.

The Diatom and Dinoflagellate maxima appear about the same time at Stat. III, and are in the surface gatherings (April 13th), before they appear (Diatoms on April 17th, and Dinoflagellates on the 19th) in the hauls from 20 to 10 faths. It is not possible to compare the actual volumes in these 20-10 vertical Nansen-net hauls with those of the horizontal, 15-minutes, tow-net. The *relative* volumes and the daily and monthly variations may, however, be compared.

The Diatom and Dinoflagellate maxima extend into May. The Diatom maximum ends between May 24th and May 28th. The Dinoflagellates are relatively more abundant than the Diatoms in May and June.

Diatoms and Dinoflagellates, like the Copepoda, decrease rapidly in numbers about April 9th, after fine weather.

Although the Dinoflagellate rise begins only a day or two after that of the Diatoms in the second half of April, the numbers of the Dinoflagellates keep up better and are relatively greater than those of the Diatoms in June.

The end of the Diatom maximum before May 28th, as well as the fall in the amount of plankton on April 9th and April 23rd, is shown by the Nansen vertical hauls as clearly as by the horizontal surface nets.

The Nansen net hauls show the Diatom maximum, throughout the water down to 20 faths., to extend from April 19th to May 24th. During the latter part of May and in June the Diatoms decrease in these vertical hauls and the Dinoflagellates increase. On June 1st there are actually more Dinoflagellates present than Diatoms.

Before the middle of June the plankton begins to increase in quantity again, and this is seen to be due to zooplankton, which now predominates over the phytoplankton. In fact the Diatom maximum is followed by the appearance of Dinoflagellates, and then of Copepoda, Sagitta and Medusæ, although the increase in one or all of these may be due to the normal life-history of the organisms and so, perhaps, be quite independent of the previous Diatom maximum.

A remarkable swarm of Lamellibranch larvæ (probably *Pecten opercularis*) was encountered outside the Bay, mainly at Stat. III, on April 5th. A few Lamellibranch larvæ are always present throughout the year. On March 31st they reach 1,000, and in the first days of April the numbers increase to two or three thousand per haul, and then on April 5th there is a sudden increase to form the maximum of 117,000 in the fine surface net at Stat. III; but other large hauls were taken also that day, as the following table shows:—

	Surf. Coarse.	Surf. fine.	Surf. Old.	Surf. Otter.	Hensen.	Nansen.	Weight.
Stat. I.	10,000	111,000	19,520	58,800	5,520	1,600	59,000
Stat. III.	30,000	117,000	24,000	86,000	1,600	2,350	110,000

The numbers remain high for the next two or three days. On the 6th one haul gave 70,000, and on the 7th the largest haul was 55,000. After that the numbers rapidly fell to 1,000 in June, and with occasional rather higher records (6,000 on October 18th), died away to end the year as it began with a few hundreds and tens. There was no such swarm of Molluscan larvæ in either of the previous years. In '08 the highest number was 7,500; and in '07, 2,500.

Comparison of Bay with Sea.

The question arises, to what extent do the tow-nettings taken across Port Erin Bay give a correct indication of the condition of the Plankton in the sea outside? On examining our results from Stats. I and III, and comparing with the records from the bay, we find as follows:—

The Total Plankton reaches a much higher level in the sea outside about the middle of May; but in June and in August the numbers are higher in the bay. Still, on the whole, the two curves follow the same course.

The Diatoms show no appreciable difference when those from outside are taken into account.

The Dinoflagellata begin their summer increase three weeks earlier in the sea outside, and in the middle of May stand at a much higher level, but at the end of May and in June, and also in August, they are considerably lower outside than in the bay. The numbers for *Ceratium tripos* are much higher throughout April outside, reaching 15,900 in the weekly average as against 1,800 in the bay. But, on the other hand, by the end of May the bay numbers have reached 21,000 as against 500 only outside.

Oikopleura shows very little difference, but the vernal maximum occurs rather earlier outside the bay.

Sagitta seems to congregate in larger numbers in the bay. It is there that all the larger hauls were made (up to 2,100), while outside it never reaches 75 in a haul.

Tomopteris (taking the three years into account) has its maximum in the open sea in June and July, while inside the bay it has a still higher maximum in October.

The Copepoda agree fairly well in dates, but the numbers per haul run larger in the bay. The largest

hauls occur, however, in the autumn, when we have no outside data for comparison.

The Cladocera appear first outside the bay in '07-'08, inside in '09; the maxima appear to correspond fairly closely in point of time, though on the whole the numbers run higher in the bay, and the catches remain large for a longer time in the bay than outside.

On the whole, the bay catches are richer per haul, but in regard to the periods of occurrence of the various organisms there does not seem to be any notable constant difference.

Annual Position of Chief Maxima.

We have drawn curves for the three important groups, Diatoms, Dinoflagellates and Copepoda, for each of the three years separately, and have also superposed the curves for the three years on one sheet in order to determine whether the groups appear in succession in the same order year after year. It is evident from what we have already stated above that the maxima of the whole plankton, and also of the component groups, are not necessarily in the same months each year—the Diatom vernal maximum, for example, may be in March ('07), April ('09), or May ('08)—but still it is possible, of course, that the relative positions may be retained, and that an early or late season may affect all groups equally.

Our curves show in '07 the Diatom maximum in March, while the Dinoflagellate line showed a considerable rise in April and May, and a further higher peak in July, and the Copepoda rise keeps about a month behind the Dinoflagellates till June, when it runs up to its early summer maximum, followed after a depression in August by a still greater maximum in October.

In '08 the Diatom maximum is in May, and the

Dinoflagellate curve is consistently a month later and reaches its climax in June, while the Copepods have two small elevations in March and June and a much greater peak in September-October. In '09 the Diatom record is peculiar, since there seem to be two spring maxima, April and June, while the Dinoflagellate maximum is in May to June and the Copepoda in July and August.

Consequently, in all three years the order of succession of the vernal maxima is the same, and when the nine curves are placed together on a sheet, although there is of course some overlapping, the Diatoms form an earlier and the Copepoda a later group, while the Dinoflagellates lie between.

The autumnal maxima are much less definite. The Copepod rise in September-October is the most marked and most regular, the Diatom increase is much less marked than that in spring and is less regular in its appearance, while the Dinoflagellate increase, if there is one, is still less marked and less constant.

Important Genera of Diatoms.

Last year we took out the five leading forms, *Biddulphia*, *Chætoceros*, *Coscinodiscus*, *Rhizosolenia*, *Thalassiosira*, for separate consideration; this year we add a sixth, *Guinardia*. The first point that one remarks in comparing the records for the two years is the close agreement in distribution throughout the year in some of the cases. In both years *Biddulphia* begins with 4 figures in January, works up to 6 figures in April, dies off to nothing at the end of May (May 20th in '08, May 27th in '09), reaches 4 figures again suddenly on September 14th (1,180 in '08, 1,200 in '09), and remains present in thousands until the end of the year. The numbers become greater, however, towards the end of this year

than they were in '08, and reach to over 50,000 on November 13th and 16th. Again, *Chætoceros* reaches 7 figures for the first time on April 27th in '08, and on April 19th and 22nd in '09, and next on May 20th in '08 and on May 12th in '09; after which the numbers fall during the late summer and rise again in autumn. This second maximum was, however, both greater and earlier this year, reaching 875,000 on September 25th, as against 70,000 on October 16th, '08.

Coscinodiscus runs through thousands and tens of thousands in the first three months of both years, and reaches 120,000 on April 13th and 14th, '08, as against 65,000 on April 7th, '09. The numbers then rapidly diminish, and reach zero on June 2nd in '08 and on June 1st in '09, and remain low with occasional increases until October, when they become steadier and rise to hundreds, bordering on 1,000, in '08, and to a few thousands (5,500 on December 14th) in '09.

Rhizosolenia presents a marked contrast to the above species in being practically absent in the first few months of the year, and having its single maximum in June. In '08 it suddenly shows 4,700 on April 13th, and in '09 equally suddenly, 5,000 on April 15th; then 40,000 on April 19th, 140,000 on May 12th, 500,000 on June 9th, 1,620,000 on June 12th, and the maximum of 2,600,000 on June 15th; '08 has 150,000 on May 20th, 1,137,500 on June 4th, and the maximum of three-and-a-half millions on June 30th.

Thalassiosira is also absent in the early months of the year, and begins with 2,000 on April 13th in '08, and 4,000 on April 15th in '09. Last year the numbers reached 80,000 on May 20th, and ended with 7,500 on June 4th; this year the highest point, 40,000, is on April 19th, 10,000 on May 20th, and 1,000 on May 24th,

after which the species is unrepresented. If, as seems possible, we had in '07 an immigration of the northern species *Thalassiosira nordenskioldii*, the numbers seem to be gradually diminishing.

Guinardia, unlike the last two genera, is present throughout the year. It works up from small numbers to 1,000 in April, 20,000 in May, and to a few millions in June—1,500,000 on June 9th, 3,000,000 on June 12th, 4,000,000 on June 15th, and 3,500,000 on June 22nd—after which the numbers gradually fall to thousands in July to September, hundreds in October and November, and tens in December. In '08 the maximum was at the same point, and the general course through the year was similar; but it did not appear in our gatherings until the middle of April—there were usually 1,000 to 4,000 during the rest of the month. In May it reached 50,000 on 20th, and 100,000 on 30th. The numbers were half a million on June 4th, and the maximum of nearly a million, twice, towards the end of the month. Then the numbers fell rapidly to thousands in July, hundreds in August to October, and tens in November and December—a very similar record to that of the present year.

According to Lohmann, at Kiel, *Sceletonema*, which is one of our rarer forms, is the commonest Diatom, and attains its maxima in May-June and September-October.

Biddulphia sinensis in Port Erin Bay, 1909.

This species of Diatom was first noticed in our bay gatherings of November 9th, '09, when 400 specimens were counted in the gathering from the coarse net and 40 from that of the fine. In the following haul on November 13th about four times the quantity was present, 1,600 in the coarse and 200 in the fine; and during the remainder of the year to December 17th numbers varying

from 1,000 and 800 down to 100 and 50 were obtained. Altogether it was found to be present in 16 bay gatherings during November and December, '09. In '08 and '09, Ostenfeld published papers* showing that this Indo-Pacific species was noticed for the first time in European waters in '03, in the Skagerrak. It was then found to be present in quantity in the South-eastern part of the North Sea round about Hamburg. From this it spread northwards to the coast of Jutland, and in the following year appeared on the Belgian coast also. And so it remained for several years. In '07 it had penetrated to the Baltic, to the North of Scotland, and southwards to the entrance to the Channel. The Norwegian observations show that *B. sinensis* was present also in the sea off Bergen in the same series of years, and recent reports show that it has continued in both these sea areas up to the present time, in each year reaching a maximum in November and the minimum in summer (May). The view is definitely held by Ostenfeld that this is a case of an exotic species which was introduced accidentally (e.g., by a ship from the East) into European waters near the mouth of the Elbe, probably in September, 1903; and the rate of dispersal from that point is used as an indication of the presence and rate of flow of currents. If Ostenfeld is correct in his interpretation of the facts, then our record shows that the species had extended to the centre of the Irish Sea in '09, and that here, as elsewhere, it reached a maximum in November (1,600 on November 13th, and 1,000 on November 16th, in one haul of a net for 15 minutes, inside the Bay). It is, however, possible that we have in all these records the unusual increase of a rare species which had previously escaped observation. It must be remembered that during the last decade far

* *Medd. Komm. Havundersog. Plankton*, I, 6, 1908; and *Internat. Revue d. Hydrobiol. u. Hydrogr.*, August, 1909.

more plankton hauls have been taken than was ever the case before, and that these collections have been most carefully and critically examined by experts. For example, in the last three years nearly 2,000 gatherings from the sea off Port Erin have been quantitatively reported upon, while before that time 50 in the year was probably a fair average number, and the examination of the material was qualitative only. So it is only what might be expected if the minuter and rarer and more critical species are now being found to be present where previously unrecorded; and we know that species which are usually rare may, through some change in the conditions, such as the competition with allied forms, become temporarily or locally very abundant. We have no proof that this is the explanation of the recent manifestation of *Biddulphia sinensis*, and we only mention it as being worthy of consideration before we accept as established the view that this species is a new immigrant from the Red Sea or more eastern waters. It must be remembered, however, as telling against this alternative explanation, that *B. sinensis* was not noticed during the two first years of our more intensive collecting, and more exhaustive examination of the material, and that a re-examination now of that earlier material reveals no trace of it. We are, therefore, inclined to consider that when this Diatom was first noticed in our nets early in November, '09, it had recently entered the Irish Sea for the first time.

Copepoda—Adults and Larvæ.

In the examination of the catches, the adult Copepoda, the Nauplii and the young intermediate stages (classed together as "juveniles") have been counted and recorded separately, and if we represent these records by

curves a certain amount of similarity in the distribution throughout the year becomes evident (see fig. 7).

In all three cases the maxima are in the summer six months, May to October inclusive. In all three cases there are two well-marked maxima, the apices of which (taking monthly averages) are in July and September respectively in the case of the Nauplii and the juveniles, and in August and October in the case of the adults. The curve for the juveniles is very like that of the Nauplii, but has much

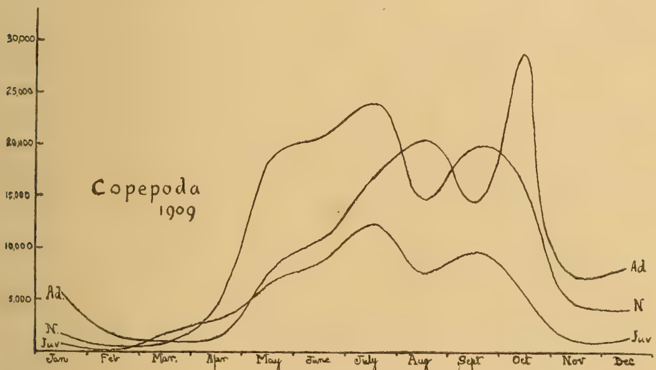


FIG. 7. Curves showing distribution of Copepoda (Ad, adults ; Juv., young ; N, Nauplii) in 1909.

less elevated peaks. The Nauplii show (on the monthly averages) an extensive maximum from the middle of May till the middle of July, with numbers ranging from 18,000 to 24,000 per haul. The curve for the juveniles only reaches about 12,000, and that only for a short time in July. Then the Nauplii curve shows the second maximum in the middle of September, reaching close on 20,000; while the curve for the juveniles shows that at that same time of year they scarcely reached 10,000 per net.

The curve for the adult Copepoda differs a little in

form from that for the juveniles. The two maxima are present in each, and the apices for the adults are about one month later than those for the juveniles—which is very much what we should expect. But the numbers for the adults are rather greater than those of the juveniles, such as 20,000 in July as against 12,000; and the October elevation runs up suddenly to close on 30,000, while the corresponding peak for juveniles in September reaches only about 10,000. It is easy from the curves to see that the Nauplius population, after reduction by about one-half, becomes the juvenile population; and although it is not quite so plain, still it looks probable that the juvenile curve is related to that of the adults, the latter being possibly reinforced in its October maximum by the immigration of swarms from neighbouring seas or from the North Atlantic Ocean.

If we now take the off-shore Stat. I, and examine the Copepoda in the same three stages, as caught in the fine surface net, we find that during the spring period (March 27th to April 26th inclusive) 19 quarter-hour hauls of the net in question were taken at that locality five miles off Bradda Head. The variation in the numbers of the different stages present from day to day is most marked in the case of the Nauplii, is less in that of the juveniles, and is least in that of the adults. The Nauplii run up to about 23,000 (at the end of March), the juveniles to 8,000 (on April 13th), and the adults to 2,000 (on April 2nd and April 21st). With a more complete series of statistics one could, doubtless, from the proportions between the totals, say week by week, arrive at a correct estimate of the death-rate at each stage, at the different times of year. The above observations from one net at one station are probably not numerous enough for this purpose, but the figures given—a reduction from

23,000 to 2,000—may perhaps be some indication of the rate of destruction.

If we look next at the Copepoda record for Stat. III., outside the Bay and along the shore to the North, during the period from the end of March to the beginning of July, we find that between March 30th and April 5th nearly all the commoner species of Copepoda increased, but the most marked abundance was that of *Oithona* (over 8,000). During the second week in April numbers were low, then about April 13th to 25th a more general increase set in: first *Acartia* became more abundant (1,600), then *Pseudocalanus* (2,600), and then *Oithona* (over 5,000) again. Numbers were low during the greater part of May, till the 21st, when *Oithona* again rose (2,750), and again (3,800) on June 7th and June 25th (3,530). Finally in August this species reached its maximum of over 20,000. *Acartia* is most abundant at beginning of June (9,880), and again on June 19th (7,980) and on August 3rd (3,900). From this it is seen that the increase of Copepoda in spring outside the Bay is mainly due to *Oithona*, in June to *Acartia*, and in August to *Oithona* again. *Pseudocalanus* does not rise to any great maxima, but relatively to the other Copepoda is more generally in evidence in April than in summer.

It would be more satisfactory if we could be certain in every case as to which adult species the Nauplii and juveniles became. In some of the more important cases they have been determined. The Nauplii at Stat. I. on April 6th, 7th, and March 31st, and at Stat. III. on April 2nd, 16th, and 17th, are mainly *Pseudocalanus*, with smaller numbers of *Temora*, *Acartia* and *Oithona*; these three latter were not very plentiful, and the names are placed in the order of their relative abundance. Most of the 8,000 " juvenile " Copepoda on April 13th appear to be early stages of *Acartia*.

Off Kiel, Lohmann finds *Oithona* to be the commonest Copepod, as we do at Port Erin. At Kiel it is five times more abundant than *Paracalanus* and nine times more than *Acartia*. Lohmann found that at Kiel *Pseudocalanus* had only a spring maximum (March). In Port Erin Bay the spring maximum is in May, and a still greater increase is found in late autumn (October).

May is the month for the chief maxima at Kiel according to Lohmann, but at Port Erin the monthly averages increase from May to August, there being well-marked peaks at the end of May and beginning of June, the end of July and the middle of August. The end of August and the first half of September shows a depression, and then comes the greatest elevation in the year about the middle of October. Lohmann states that at Kiel there are few Copepoda in July and August. At Port Erin they are quite abundant then. In the Bay on August 2nd, '09, there were close on 20,000 of *Pseudocalanus* alone in one net. It looks as if our maxima were rather later than those at Kiel, Lohmann's May maximum being represented here in June, and his August depression corresponding to the September condition here.

Selected Copepoda.

In our last report we gave the full particulars of the distribution in the Bay, throughout the year, of six important Copepoda. This year we have taken out the same series, along with a few additional forms, as follows: *Calanus helgolandicus*, *Pseudocalanus elongatus*, *Anomalocera pattersonii*, *Acartia clausi*, *Centropages hamatus*, *Oithona similis*, *Temora longicornis*, *Paracalanus parvus*, and *Microcalanus pusillus*, which for the sake of brevity

we shall allude to in the rest of this discussion by their generic names. We have again made out detailed lists of the occurrences on every occasion in '09, but we do not think it necessary to publish these: a comparison with last year's results will probably suffice.

Pseudocalanus is again one of the most abundant forms. It is present throughout the year, and is represented in nearly every gathering, and in many months by high numbers, for a Copepod. The greatest numbers caught in single hauls reached over 3,000 on occasions in January, February and March, 7,000 in May, 5,000 in June, 9,200 in July, 19,250 in August, 14,000 in September, and 23,200 and 16,900 in October, 8,100 in November and 4,000 in December. These numbers are rather higher than those of last year and not quite so high as those of '07. Many of the monthly averages, per net, run into thousands, and for October the number is 8,990. In the earlier part of April it seems to be more abundant in the deeper nets, and later in the month is more on the surface.

Calanus (see Pl. B, fig. 4) is present throughout the year, although in some months only a few individuals were caught at a time. The numbers remain low, for the most part units and tens, during the first four months, and then on May 27th run up suddenly to 1,500. This was probably an exceptional swarm that entered the Bay, as next day the same net caught 95 only. In June the numbers were generally in the hundreds, and twice (18th and 19th) exceeded a thousand. July was much the same, with 1,500 on the 6th and 2,000 on the 21st; August and September showed units and tens and occasional hundreds, while October had 1,800 on the 16th and 4,200 on the 18th. The end of the year like the beginning gave low numbers only. This agrees fairly well with previous years, but the increase in early summer is here later than

in '08, though almost identical in position with '07 (fig. 8). There has been in '09 no evidence of a really great swarm in July or August such as we have occasionally seen in former years; but a chance observation made in July shows how easy it is to miss such an occurrence. The official gatherings taken on July 15th and 21st give no evidence of any unusual numbers, but

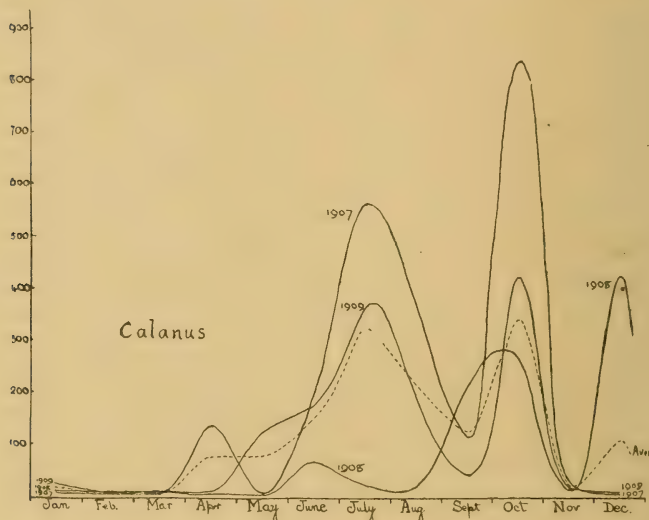


FIG. 8. Curves for *Calanus* in '07, '08 and '09. The dotted line shows the average for the three years.

ordinary tow-net gatherings, taken by Mr. Gravely and Mr. Dakin for class purposes on July 17th and 19th, yielded enormous hauls of *Calanus*, only portions of which were preserved, but which it is estimated must have reached at least 20,000 per net.

We show here (fig. 9) what we take to be the ovum, or rather the unhatched nauplius (measuring 0·68 mm. in diameter) of *Calanus helgolandicus*. That species has

never been taken with extruded eggs attached to the genital segment, and it is therefore highly probable that the fertilised ova are set free directly into the sea. We have observed this pelagic egg from time to time for some years, but as the embryo was too immature we were unable to assign it to any animal. A few were taken in the '09 collections which clearly show the Nauplius inside.

We add here a sentence published* more than twenty years ago by our friend the late Mr. Isaac C. Thompson, in regard to the ova of *Calanus* found in gatherings from the North of Norway, which he was examining at that

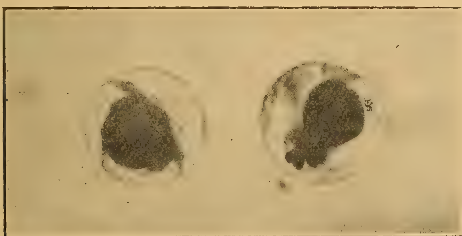


FIG. 9. Pelagic egg of *Calanus*, ×23·5.

time:—". . . in some of the localities about the North Cape . . . this species [*Calanus finmarchicus*, Günner] forms almost the entire mass in the tow-net. Its profusion here enables us to clear up a most interesting question. It has been often remarked that in this, as in some other species of Copepoda, the precise manner of ovi-position is mysterious inasmuch as females with ovisacs have never been noticed, though carefully looked for . . . . It has often struck me as probable that *Calanus finmarchicus* casts its ova directly into the sea just as fishes do, and its profusion in these northern localities has furnished the opportunity of establishing what seems to be a clear proof

* *Trans. Liverpool Biol. Soc.*, Vol. III, pp. 80, 81, 1889.

of the truth of this theory. For on examining many hundreds of them together, especially in the collection No. 4, made at Hammerfest, I find small quantities of specially granular ova scattered about, and in two instances as if just ejected from the animal, but entangled by the swimming feet as the animal met its doom. It is confirmatory of these being the ova of *Calanus* that they appear only in such other gatherings as contain in great abundance this species and it almost exclusively."

Acartia (Pl. B, fig. 3) is present throughout the year, but is usually not very abundant. In January, February and March the numbers are mostly units and tens, rarely reaching hundreds, the highest being 450 on February 25th. In April there is an increase to 1,000, on the 19th; May is lower, reaching only 800; June and July show several hauls of over 2,000; August has 1,400 and 1,100; September reaches 2,350 on the 29th; October the same number on the 27th; November shows hundreds only, and December the same, with 1,100 on the 17th. This agrees fairly well with last year's record, the highest numbers are again in September and October, but last year's maximum, 11,000 on October 8th, was much higher than anything attained this year.

Oithona is the most generally abundant species throughout the year. The numbers run into thousands in every month except April, and the maxima are 15,800 in January; 10,000 in May; 20,000 in July, and again in August; and 50,000 on October 18th. On the whole these numbers are greater than those of last year, when the maximum was reached with 40,000 on September 14th; the previous year showed 30,000 on September 20th. But the general curve of the species throughout the year is the same, and the climax is reached in late autumn in each case.

Temora forms a contrast to *Oithona* inasmuch as it is less generally distributed throughout the year, and in '09, for example, was not represented in any of our nets during six out of the fifty-two weeks. In fact, *Temora* is practically absent from the middle of October until the end of March, reaches 100 late in April and 1,000 on May 8th, 5,000 on May 27th, over 3,000 several times in June and July, and 9,000 on August 2nd; after which the numbers fall off to hundreds and tens until October 9th, and then fall further to tens and units with occasional periods when the species is absent. *Temora*, as we have pointed out before, is distributed irregularly in swarms.

Paracalanus is again, as it was in '08, absent during a considerable part of spring and summer. It is unrepresented in our nets during seven entire weeks. It is present in fair quantity early in January (2,000 in one haul on January 4th), diminishes during February and March, is frequently absent in March, April and May, reaches a few hundreds occasionally in June and July, a thousand a couple of times in August and again in September (1,900 on September 14th), and has its maximum about the middle of October with 4,000 on the 9th, 8,700 on the 18th, and 2,800 on the 23rd. After that the numbers remain in the hundreds, ending with 420 and 170 on December 29th.

The totals of the above six important species of Copepoda for the year, in the order of their abundance, are:—

Oithona similis	465,066	*Temora longicornis*.........	62,659
Pseudocalanus elongatus	309,973	*Paracalanus parvus*	54,120
Acartia clausi...............	63,373	*Calanus helgolandicus* ...	21,412

The actual numbers are of no importance except as an indication of the relative abundance. It is clear that *Oithona* and *Pseudocalanus* far outnumber the others.

On plotting the weekly averages of these six species and drawing curves through them the fact comes out that taking them all together the great elevations are found in the six months May to October and the minima are in the six winter and spring months, November to April inclusive. Although the maximum for *Acartia* is in June, for *Temora* in August, for *Pseudocalanus*, *Paracalanus* and *Oithona* in October, and for *Calanus* in July and October, when all are put together it is evident that the Copepoda are a summer and autumn group, and in that respect contrast strongly with the Diatoms, for example.

A few other less important species which have been mentioned in the previous reports will now be dealt with.

ANOMALOCERA is practically absent, except for an occasional straggler, up to the end of March; 25 young specimens on the 30th and 10 on the 31st; 45 and 15 on April 7th in mid-channel; 25 to 30 on the 13th, 14th, 15th, 19th, and 45 on the 24th; otherwise the numbers are units and tens. May shows a sudden increase to 300 on the 28th, and after 40 on the 1st and 60 on the 4th of June *Anomalocera* is practically absent during the remainder of the year. In '08 it occurred from the middle of April to the middle of September; in '07 it was present in the Bay until November.

CENTROPAGES HAMATUS is never an abundant form. It is practically absent until May, when it appears in units and tens, reaching 160 at the end of the month, 200 several times in June, 300 in July and again on August 2nd, after which the numbers rapidly fall to tens and units again and so remain until the end of the year. This is one of the forms that seem to be commoner in the Bay than in the sea outside.

MICROCALANUS PUSILLUS, Sars. It will be remembered that in this Report, Part I, p. 165, it was

shown that *Microcalanus pusillus* appeared in the deep water, in mid-channel, to the South-west of the Isle of Man in large numbers in the late summer of '07, and spread late in August and early in September up to the surface (September 11th) and into the shallow waters, until by September 21st it had entered Port Erin Bay and seemed to be generally distributed. It remained in evidence until the end of the year. This was interpreted in the Report as being possibly an instance of the invasion of the district by a non-indigenous species. *Microcalanus* does not appear in the '06 or earlier records. It was only described by Sars in '03, and its distribution was then limited to a few deep-water localities in Norway. It has since been found off the N.W. coast of Scotland, and (doubtfully) from the West of Ireland. It does not appear to be recorded from the English Channel. If the species was a new immigrant in the autumn of '07, it apparently neither left again nor died out, as we find it persisting throughout the winter in Port Erin Bay. Altogether it appeared in 59 gatherings between August 24th and December 23rd, '07. In the '08 series of gatherings, *Microcalanus* appears first on January 8th in the Bay. In April it usually occurs only in the Hensen and Nansen closing nets fishing in the zone from 20 up to 10 faths. In autumn likewise (August 5th to September 14th) it occurs only in the Hensen and Nansen closing nets and in the weighted open tow-net which worked in from 10 to 5 faths. The species was present in 49 gatherings during '08, extending from January 8th to September 14th.

In '09, *Microcalanus* is present 123 times in all, and occurs in the records for every month except July, October and November. Outside the Bay it is usually confined to the Hensen, Nansen and weighted nets. It occurs, how-

ever, six times in the surface net worked with an otter-board, four of these being at Stat. I. and two at Stat. III. In the other surface nets it occurs on three days at Stat. I. and on three days at Stat. III. The greatest number is 500 in the Nansen net hauled from 60 faths. to the surface on April 8th, in mid-channel; but fairly large numbers were also obtained sometimes on the surface in the bay, *e.g.*, 200 on February 24th, 300 on April 27th, 200 on August 23rd, and 400 on December 21st.

Consequently, having once appeared in the district in '07, this species seems to have remained during the last two years, and, with the exception of the great haul obtained on its first appearance (September 12th, 1907, 2,000 in net at 10 faths. and 2,500 in net at 20 faths.), the numbers during '09 seem to be on the whole larger than they were in '07 and 08.

The alternative to this being a case of an invasion by a more northern species is that it is merely one of the smaller and rarer forms which had hitherto escaped notice. It is only 0·7 mm. in length, and was only made known to science in '03; and since then it has been found, by careful and critical investigation, in several distant localities. Previous to our recent "intensive study," it may have passed through the meshes of the coarser nets generally used, or may have remained uncaptured through its rarity, or if captured may not have been distinguished from other small forms. There are various others of the smaller and rarer forms that we now get more frequently, first because of the more perfect collecting, and secondly because of the more exhaustive examination of the material collected.

We put this forward, then, as a possible alternative explanation, not merely in this case, but in that also of other rarer species which seem to make their appearance

suddenly in an area where previously unknown. It is possible that the "sudden appearance" which leads to the identification is due to a local increase in numbers permitted by some change in the environment.

Outside the bay, *Microcalanus* behaves pretty well in agreement with Sars' description of it as a mid-water form. It appears in the open-sea nets 68 times in the three years. In 40 of these, or almost 60 per cent., it was present only in the vertical nets; in only 15, or 22 per cent., does it appear in the surface nets; and in about 25 per cent. in the "weight" net. Thus it is evident that *Microcalanus* is at least not a surface form. Paulsen finds it in quantity in deep hauls to the North of Iceland.

Cirripedia.

The *Balanus* larvæ are rather interesting. The Nauplii (fig. 10, p. 319) begin on February 6th, reach 3,000 on the 24th, 12,000 on March 31st and 10,000 on April 13th; decline to 1,100 on April 22nd, to 150 on May 12th, and disappear at the end of May. Those of the Cypris stage (fig. 11) appear first on April 13th, reach 900 on May 12th, and disappear at the end of June. The Nauplii are at their climax in early April, the Cypris in the middle of May.

In times of first appearance (e.g., Nauplii on February 22nd in '07, February 13th in '08, February 6th in '09) and of maxima these figures agree substantially with those of the two previous years.

Cladocera.

The constancy of this group is remarkable—*Evadne* ranging from March or April to the end of August or September in each of the three years, and *Podon* from the

latter part of March or May to October. The present year seems to have been earlier than its two predecessors in respect of this group, as the following table shows:—

	1907.
Evadne nordmanni	......March 29 to September 20
Podon intermedium	......March 26 to October 9
	1908.
Evadne nordmanni	......April 11 to August 27
Podon intermedium	......May 26 to October 24
	1909.
Evadne nordmanni	......March 6 to September 21
Podon intermedium	......March 15 to October 2

As to the details of the present year, *Evadne* appears first in the Bay on March 6th, and the numbers remain small in March and April, but rise rapidly into the thousands in May, reaching 12,000, in the Bay, on May 24th, and 13,000 on the 27th, and 12,000 in the coarse surface net outside the Bay on May 24th—another case like those quoted in our previous reports of the marked equality in hauls indicating an even distribution. *Evadne* remains fairly abundant in June and July. After the first week in August it only occurs on three occasions, the last haul being 25 in the Bay on September 21st. The maximum in '08 was 12,500, on June 10th. In '07 the numbers were much lower throughout.

Podon occurs first in the Bay on March 15th, and the numbers remain small until May. The maximum in the Bay is 650, on May 8th. In the sea outside it reaches 1,000, on May 24th. It is much more constant in the later months than *Evadne*, being present mostly in hundreds and tens, and with but few breaks, until October 2nd, when 80 were taken by the coarse net in the Bay.

TOMOPTERIS.

The species of *Tomopteris* which occurs in our district is the species which Daniele Rosa* names *Tomopteris* (*Johnstonella*) *catharina* (Gosse), and which has commonly been called *T. onisciformis* by Carpenter and others in this country, and *T. helgolandica* by Greeff, Apstein and others on the Continent.

Tomopteris is rather irregularly distributed over the months, is rarely very abundant, and has rather a different record in the three years. In all, we have captured 1,683 specimens in 255 hauls of the nets, and in 1,680 hauls no specimens were obtained. The distribution is sporadic, and no localities or zones seem to be more frequented than others. Bay and sea outside, deep and surface nets, seem to be about equally represented in the record. In most of the hauls a few specimens only were obtained; many show one *Tomopteris* only, and in a large number of hauls in each of the years none were captured.

In '07 no specimens were obtained in January, February, March, May, June and July; in '08 none in January, March, May and July; in '09, which has the most complete record, May is the only month not represented. There are, then, no May specimens in any of the three years. In most of the remaining months throughout the three years the average numbers obtained in a haul are low units, such as 1, 2, 3 and 4; but in March '09, the number was 12·5, in August '08 it was 9, in September '07, 11·7, and in September '08, 14. The greatest numbers obtained in single hauls were:— March 31, '09 = 68; April 15, '09 = 28; April 17, '09 = 34; August 4, '08 = 23 and 20; August 7, '08 = 200;

* *Raccolte Planctoniche, &c.*, V. Anellidi, p. 247, Firenze, 1908.

August 15, '07 = 25; August 19, '08 = 50; August 20, '08 = 35; August 26, '08 = 34; September 12, '08 = 38 and 37; September 15, '08 = 120; September 19, '07 = 85; September 20, '07 = 95 and 65; October 7, '08 = 65. Most, but not all, of these large hauls were taken with the shear net or the large Nansen. If we take the shear net as equivalent to 15, and the large Nansen (100 cm. diam.) as equivalent to 10 of the small ordinary nets, and make out monthly averages per unit net, it is clear that the maximum occurs in October in the three years taken together, and the same result is obtained if we eliminate all the catches with larger nets and with deep nets in the open sea, and take into consideration only the hauls with the small open tow-net across Port Erin Bay. There were 515 of these, representing every month in each of the three years, and when combined they give the following averages per net:—

Jan. ...	0·6	April ...	0·1	July ...	0·5	Oct. ...	2·0
Feb. ...	0·1	May ...	0	Aug. ...	0·7	Nov. ...	0·8
Mar.......	0	June ...	0·1	Sept. ...	0·8	Dec. ...	0·9

Although in '09 *Tomopteris* is more fully represented throughout the year, still nearly twice as many specimens per haul were obtained in '07, and nearly thrice as many in '08. The figures for the three years separately are as follows:—

	Total hauls.	Total hauls in which Tomopteris occurs.	Total No. of Tomopteris.	Average No. in *all* hauls.	Average No. in hauls where represented.
1907......	610	63	399	0 65	6·3
1908......	571	103	945	1·65	9·17
1909......	754	89	339	0·45	3·8
3 years	1,935	255	1,683	0·87	6·6

Sagitta.

Sagitta is represented in all months. The numbers keep low (under 50) from January to April inclusive, and then advance to over 200 late in May, over 500 on June 4th, 1,975 and 1,344 on June 9th, 1,012 on June 18th, over 400 late in July and early in August, after which the numbers run rapidly down to under 30, and then remain for the most part at units during September and October. In November the highest number is 115, and in December 164. The smoothed curve representing monthly averages shows, then, one great peak in June and slighter elevations late in July and early in August, and again in November and December. The minima are in the first four months of the year and in September and October. The addition of the catches made in the sea outside the bay during April and in summer does not materially affect the general shape of the curve.

When we compare these results with those of the two previous years, we find that although each year has some peculiarities, there is a general similarity. In '07 there was a maximum in July-August and a second lower peak in October-November. In '08, when the numbers as a whole were lower, there was a maximum in the open sea on August 7th, and again early in November. Combining the three years, we find two distinct maxima in the year, the first, greater one, in June-August, and the second, much smaller, in October-November. Looking at the largest hauls in each year, in the ordinary tow-nets we find:—

In '07: On August 12th, 1,000; on August 15th, 1,800; and on November 4th, 324.

In '08: On June 30th, 750; on August 7th, 256; on September 14th, 220; and on November 6th, 108.

In '09: On June 9th, 1,975; on August 2nd, 498; on November 1st, 115; and on December 17th, 164.

In the larger nets, on occasions, some even greater numbers were obtained, such as 2,300 in the shear-net, on March 31st, '09, 2,050 in the large Nansen net on August 4th, '09, and 3,408 in the Yngel net on August 8th, '08. If we omit these larger nets, the monthly averages for the three years in the open sea are in all cases smaller than the corresponding figures for bay hauls.

The following table gives the totals for the three years, and shows a remarkable constancy in the total number of Sagitta captured, and in the numbers per haul. When 44 is the average number caught, it is remarkable that the poorest year does not fall below 42, and the richest does not rise above 48:—

Year.	Total equivalent hauls.	Total hauls in which Sagitta is represented.	Total No. of Sagitta.	Average No. in all hauls.	Average No. in hauls where represented.
1907......	610	370	17,658	29	48
1908......	571	353	14,675	26	42
1909......	754	453	19,280	26	43
1907-8-9	1,935	1,176	51,613	27	44

In '07 the average number per haul at the maxima is 126 in July and 127 in November, and in '09 the greatest average is 209 per haul in June. The numbers are not so great in '08. The minima in '07 and '08 are 2 per haul, in February. Sagitta seems to breed twice in the year (spring and autumn), although some reproducing individuals may apparently be found in any month. The summer maximum is probably the result of the spring brood, and it is noteworthy that this climax in the Sagitta population curve occurs distinctly later than the great

	Port Erin, 1907-8-9.	Clyde, 1901-2.	Valencia, 1895-98.	Plymouth, 1903-4-5.
January				Present to common
		Only large adults		
February				Rare to common
	Scarce (Under 50 per net)			
March	No very young 12·5-18 mm. (Mature ova)	Early stages begin, 2 mm. upwards	Scarce in Spring, 10-35 mm.	Rare or absent
		Scarce		
April	9-20 mm. (Mature ova)			
May	(Over 200)			Rare to present
June	(500 to 2,000) 8-15 mm. (Larger ones with mature ova)			
July	First maximum 6·5-19 mm.	Fairly common 5-10 mm.	Young stages getting common	Present or absent
August	Numbers decreasing (Mature ova)	Scarce		
				Rare to present
September	8-18 mm. (few only) (Mature ova)	Scarce, 10-15 mm.		
October		Adults and early stages		Present to very common
	Second maximum 11-17 mm.		Shoals of medium-sized individuals, 10-15 mm.	
November		Sudden increase		
				Rare to common
December	Decreasing	Scarce, 15·20 mm.		

vernal maxima, and at a time of year when several of the most important groups of organisms in the sea are on the wane.

We can obtain some information in regard to the distribution of Sagitta throughout the year in other parts of the British seas from the records of E. T. Browne* in the Clyde, Gamble† at Valencia, and Gough‡ at Plymouth. If we arrange the essential facts in columns opposite the months we get the table shown on page 305.

The Plymouth record seems to show that large quantities are seldom obtained except in October, and that the minimum is in March. At Valencia there are shoals in October-November, and a scarcity in spring. In the Clyde there is an increase in October-November, and again a scarcity in spring, in August and in December, and the organism is fairly common in July.

Returning now to the Port Erin column, we find it agrees with all the others in showing a scarcity in early spring; has a marked maximum in June-July which has not been noticed elsewhere; and has a second but smaller increase in October-November which seems indicated at the other localities also.

In the Baltic, according to Lohmann, *Sagitta* is most abundant in September and onwards through the winter—under possibly rather different conditions of temperature and salinity from those of the Irish Sea.

OIKOPLEURA.

The common *Oikopleura dioica* is present in our collections throughout the year, and is well represented in every month. There is a marked winter minimum in

* *Proc. Roy. Soc. Edin.*, Vol. XXV, p. 779, 1905.

† *Royal Irish Acad. Proc.*, Series III, Vol. V, p. 745, 1900.

‡ *North Sea Investigations*, Blue-books Cd 2670, 1905, and Cd. 3837, 1907.

December, January, February and March, when there were never more than a few hundred in a haul. It is well represented from April to November inclusive, and gets above 3,000 in a haul in April, May, June, July, August and September. The greatest hauls were:—April 13th, 4,600; April 19th, 5,600; May 27th, 3,600; June 22nd, 3,600; July 3rd, 3,350; July 31st, 3,000; August 2nd, 3,000; August 23rd, 3,350; September 11th, 5,300; September 18th, 7,600; September 25th, 3,500.

The smoothed curve representing monthly averages shows a rounded elevation extending from April to July, and reaching its highest point, a little over 3,000, in June; a slight fall in August and a higher and much sharper peak in September, reaching a maximum of nearly 5,000. Comparing this with the two previous years, we find that there is very close agreement with '07, even to such details as the amount of the greatest catch obtained in April, 5,500 per net in '07 and 5,600 in '09. There is, however, the great rise to 7,600 in September this year, which agrees with the September maximum of 7,000 in '08. So that, finally, this year combines the maxima of '07 and '08. The winter minimum remains constant for the three years.

Oceanic and Neritic Species.

In the tables below the attempt is made to determine whether the plankton in Port Erin Bay during the last three years has been more Neritic or more Oceanic in character. We regard as Oceanic species those that typically inhabit the open ocean, although they may also be found in coastal waters, and which have no fixed or resting bottom stages in their life-history, and are, in short, holoplanktonic (Haeckel) Neritic species are those typically found in coastal and comparatively shallow

waters. Most of them have fixed or resting bottom stages in their life-history, and so fall into Haeckel's mero-plankton, but some Neritic forms are holoplanktonic, being permanently free.

Table I gives a list of the species found during '09, with the number of days in each month on which they occur. It also shows the number of species present each month, and the proportion of Oceanic species. It will be seen that only in two months (January and December) do the Oceanic forms outnumber the Neritic, while in July the two are equal. For the other months the percentage of Oceanic species ranges from 40 to 48·5. This would tend to show that Port Erin Bay is rather more Neritic than Oceanic in character; that is, that in most months more Neritic than Oceanic species occur. But that, although true, is not the whole truth, since it recognises in each month only the number of species that have occurred, and not the total number of their occurrences, nor the average number of times that Oceanic or Neritic species occurred in each month.

Consequently, it is interesting to consider Table II (p. 312), which gives the mean occurrence or average number of days per month on which Oceanic and Neritic forms, respectively, occurred, obtained by dividing the sum of the number of days on which the various forms (Oceanic or Neritic) occurred (= total occurrences) by the number of species. The factor thus obtained shows the relative constancy of the two groups of species, and the table shows that the average for the Oceanic forms is much higher than for the Neritic, that is, that the Oceanic forms are a much more constant feature of the plankton. Further, we show the percentage that each average number of occurrence-days is of the total possible number of plankton-days in that month, and we are

TABLE I.—1909.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total days worked		11	16	16	8	7	9	7	8	8	7	8	9
Achnanthes taeniata	N	—	—	1	—	—	1	—	—	—	—	—	—
Asterionella bleakeleyi	N	9	16	16	2	—	—	—	—	1	—	3	—
,, japonica	N	—	—	—	—	—	—	—	—	2	1	5	—
Bacillaria paradoxa	N	3	9	3	5	2	—	—	1	—	—	4	4
Bacteriastrum sp.	O	1	—	1	—	—	—	—	—	—	—	—	—
Biddulphia mobiliensis	N	11	16	16	8	7	—	4	4	8	7	8	9
,, sinensis	N	—	—	—	—	—	—	—	—	—	—	6	2
Chætoceros boreale	O	2	1	—	6	7	3	—	—	3	—	—	—
,, contortum	N	5	3	12	6	5	—	1	4	6	5	7	4
,, criophilum	O	3	10	11	8	1	—	2	3	6	5	7	8
,, debile	N	3	13	16	7	7	—	1	5	8	7	8	7
,, decipiens	N	11	16	16	8	7	1	2	6	8	7	8	9
,, densum	O	—	—	—	—	7	5	6	7	8	4	8	2
,, diadema	N	—	—	—	1	1	—	—	—	—	—	—	—
,, sociale	N	1	1	13	5	7	—	2	—	3	1	—	—
,, teres	N	10	16	16	8	7	5	1	5	8	6	8	9
Coscinodiscus concinnus	N	11	16	16	8	7	1	1	3	1	3	8	9
,, grani	N	—	1	3	1	—	—	—	—	—	1	8	9
,, radiatus	O	11	16	16	8	5	4	2	3	2	5	8	9
Ditylium brightwellii	N	1	5	9	1	1	—	—	1	3	1	7	8
Eucampia zodiacus	N	—	—	1	1	5	6	—	—	—	1	2	—
Guinardia flaccida	N	1	1	1	5	5	9	5	2	4	1	6	1
Lauderia borealis	N	—	—	2	5	5	3	—	—	1	—	4	2

TABLE I.—1909—*Continued.*		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total days worked		11	16	16	8	7	9	7	8	8	7	8	9
Melosira borreri	N	—	1	—	1	—	—	—	1	—	1	3	—
Nitzschia seriata	N	—	2	—	—	—	—	—	—	—	—	—	—
Rhizosolenia semispina	O	—	—	10	3	7	7	7	8	8	3	7	—
,, setigera	N	—	—	4	1	—	—	—	—	—	—	7	—
,, shrubsolei	N	—	5	6	3	6	7	7	5	6	2	6	—
,, stolterfothi	N	—	—	—	—	5	6	6	3	—	—	—	—
Streptotheca thamensis	N	1	4	1	4	—	—	—	—	—	4	8	7
Thalassiosira gravida	N	—	—	—	1	—	—	—	—	—	—	—	—
,, nordenskioldii	N	—	—	—	3	4	—	—	—	—	—	—	—
Tintinnopsis sp.	N	—	—	—	—	—	—	—	—	3	1	8	—
Ceratium furca	O	7	11	8	6	6	9	6	7	3	4	5	8
,, fusus	O	3	13	10	6	6	9	7	4	5	3	8	9
,, tripos	O	11	16	6	6	6	9	7	8	8	6	8	9
Peridinium sp.	O	3	—	1	6	7	9	6	5	1	1	2	3
Trochiscia sp.	N	—	—	—	1	1	2	3	3	6	1	—	—
Noctiluca miliaris	N	7	6	—	3	—	2	—	1	2	1	8	—
Pleurobrachia pileus	O	—	1	2	1	—	2	—	—	4	2	1	—
Autolytus prolifer	N	2	4	2	1	1	6	5	2	—	—	1	—
Sagitta bipunctata	O	10	15	15	7	7	9	7	8	8	6	8	9
Tomopteris catharina	O	8	2	—	—	—	—	5	3	1	3	4	5
Acartia clausi	O	10	16	13	5	5	9	7	8	8	7	8	9
Anomalocera pattersoni	O	2	—	—	1	2	—	—	—	—	—	—	—
Calanus helgolandicus	O	11	15	12	4	6	9	7	8	8	7	8	8

Table I.—1909—*Continued.*		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total days worked		11	16	16	8	7	9	7	8	8	7	8	9
Candacia armata	O	2	1	—	—	—	—	—	—	—	—	1	3
Centropages hamatus	N	1	—	1	—	4	6	6	6	6	1	2	6
Isias clavipes	N	—	—	—	—	3	7	—	2	5	3	1	—
Labidocera wollastoni	N	—	—	—	—	—	—	—	—	—	—	2	—
Metridia lucens	O	3	—	—	—	—	—	—	—	—	—	1	3
Microcalanus pusillus	O	3	5	2	1	1	—	—	1	1	—	—	4
Oithona similis	O	11	15	16	8	7	9	7	8	8	7	8	9
Paracalanus parvus	O	11	14	10	1	1	4	6	8	8	7	7	9
Parapontella brevicornis	N	—	—	1	—	2	—	—	1	—	—	1	—
Pseudocalanus elongatus	O	11	16	16	8	7	9	7	8	8	7	8	9
Temora longicornis	N	1	3	13	8	7	9	7	8	8	4	7	—
Evadne nordmanni	N	—	—	1	3	7	7	7	2	1	—	—	—
Podon intermedium	N	—	—	1	1	7	5	7	7	5	1	—	—
Oikopleura dioica	O	6	14	12	8	7	9	7	8	8	7	8	5
Total O + N		36	36	41	45	42	33	32	38	40	39	46	32
Total O		20	17	17	18	18	16	16	17	19	17	19	18
Percentage O		55·5	47·2	41·4	40	42·8	48·5	50	47·4	47·5	43·6	42·2	56·2

	Table II.—1909	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Total days worked	11	16	16	8	7	9	7	8	8	7	8	9
Oceanic.	Total No. of species ...	20	17	17	18	18	16	16	17	19	17	19	18
	,, occurrences	129	184	161	93	95	115	96	105	106	84	115	121
	Mean occurrence	6·45	10·82	9·42	5·16	5·27	7·18	6·00	6·17	5·58	4·93	6·05	6·72
	Percentage of possible	58·6	67·6	58·7	64·5	75·3	79·8	85·7	77·1	69·7	70·4	75·6	74·6
Neritic.	Total No. of species ...	16	19	24	27	24	17	16	21	21	22	27	14
	,, occurrences	76	138	161	101	113	83	65	72	95	60	146	86
	Mean occurrence	4·87	7·26	6·71	3·74	4·71	4·88	4·06	3·43	4·52	2·73	5·41	6·14
	Percentage of possible	44·3	45·4	41·9	46·7	67·3	54·2	58	42·9	56·5	39	67·6	68·2

inclined to regard these percentages as the most valuable indications of the relative occurrences. For example, in July, Oceanic species occur on the average six days and Neritic a little over four days; but the six represents nearly 86 per cent. of the possible occurrences in that month, and the four is 58 per cent. It must not be supposed that June, with 16 species showing 115 occurrences, is necessarily more constant than July with 16 species making 96 occurrences, since samples were taken on nine occasions in June but only on seven in July. The numbers for mean occurrence, seven and six, are therefore in this case not instructive, and the percentages 79 and 85 are, we consider, more correct. But as we give in the tables all the figures bearing on the problem, any possible false impression can be easily rectified.

If we enquire further into the apparently marked Oceanic character of December, with 56 per cent. of Oceanic species in the table, we find that *Metridia lucens* is present (only in December, November and January), while the common Neritic forms *Temora, Eucampia, Asterionella, Chætoceros sociale, Rhizosolenia, Noctiluca, Pleurobrachia* and *Autolytus* are all absent, and also the less prevalent *Podon* and *Evadne.* The same explanation can be given in the case of January, the month with the next highest percentage of Oceanic species, and this supports Gough's remark that Oceanic character is largely due to absence of Neritic forms, not to any unusual abundance of Oceanic species. One of the most notable points brought out by this enquiry is the fairly even numbers of Oceanic and Neritic species occurring in each month, since the percentages in Table I range only from 40 to about 56.

Treating the records for '08 in the same way, we find that the totals of Table I (the details of which need not be printed in full) are, as shown on p. 314:—

Table I.—1907.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total days worked	2	3	4	17	3	3	4	16	17	4	4	4
Total O + N	20	29	24	44	35	31	28	27	40	33	35	28
Total O	10	13	11	20	14	13	14	15	21	15	19	16
Percentage O	50·0	44·8	41·6	45·4	40·0	41·9	50·0	55·5	52·5	45·4	54·3	57·1

Table I.—1908.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Total days worked	4	5	4	14	5	8	5	6	10	21	5	4
Total O + N	26	23	20	50	40	38	28	35	37	45	40	28
Total O	14	12	11	19	17	19	17	17	17	19	19	17
Percentage O	53·8	52·2	55·0	38·0	42·5	50·0	60·7	48·5	45·9	42·2	47·5	60·7

Table II.—1908.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Total days worked	4	5	4	14	5	8	5	6	10	21	5	4
Oceanic.	Total No. of species ...	14	12	11	19	17	19	17	17	17	19	19	17
	„ occurrences	40	44	31	128	67	107	69	77	125	297	71	44
	Mean occurrence	2·86	3·66	2·82	6·74	3·94	5·63	4·06	4·53	7·32	15·63	3·74	2·59
	Percentage of possible	71·5	73·2	70·5	48·1	78·8	70·4	81·2	75·5	73·2	74·4	74·8	64·7
Neritic.	Total No. of species ...	12	11	9	31	23	19	11	18	20	26	21	11
	„ occurrences	28	30	23	250	69	83	35	46	92	271	60	21
	Mean occurrence	2·33	2·73	2·55	8·32	3·00	4·37	31·8	2·55	4·6	10·42	2·86	1·91
	Percentage of possible	58·2	54·6	63·7	59·4	60·0	54·6	63·6	42·5	46·0	49·6	57·2	47·7

	Table II.—1907.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Total days worked	2	3	4	17	3	3	4	16	17	4	4	4
Oceanic.	Total No. of species ...	10	13	11	20	14	13	14	15	21	15	19	16
	„ occurrences	16	25	29	178	36	31	47	129	205	41	52	47
	Mean occurrence	1·60	1·92	2·73	8·90	2·57	2·38	3·36	8·60	5·00	2·73	2·74	2·94
	Percentage of possible	80·0	64·0	68·2	52·3	85·6	79·3	84·0	53·7	29·4	68·2	68·5	73·5
Neritic.	Total No. of species ...	10	16	13	24	21	18	14	12	19	18	16	12
	„ occurrences	11	31	25	166	37	30	37	69	129	32	42	34
	Mean occurrence	1·10	1·94	1·92	6·92	1·76	1·67	2·64	5·75	6·79	1·78	2·62	2·83
	Percentage of possible	55·0	64·6	48·0	40·7	58·6	55·6	66·0	35·9	39·9	44·5	65·5	70·8

The total number of working days is lower, and the total number of species obtained is, in most months, lower. The percentages of Oceanic species (38 to 60·7) show a wider range than in '09, and more of the months show an Oceanic character (5 in '08, 2 in '09).

The second table for that year for comparison with that of '09 is on p. 315, and shows that:—

The preponderance of Neritic species in April is chiefly due to Diatoms. For example, *Biddulphia aurita* and *Thalassiosira gravida* occur only in this month. *Asterionella bleakeleyi*, *Coscinosira polychorda*, *Nitzschia seriata* and *Rhizosolenia setigera* occur only in one other month; *Thalassiosira nordenskioldii* and *Achnanthes tæniata* in two others; and *Ditylium brightwellii* and *Chætoceros sociale* in three others.

Our third available year, '07, treated in the same way, on p. 314, shows the following record:—

The percentages of Oceanic species range from 40 to 57 (being thus intermediate between '08 and '09), and four of the months show an Oceanic character.

The most noteworthy points in this record are:—(1) the unusual variation in the number of Oceanic species—10 to 21; and (2) the very low percentage of possible occurrences in both Oceanic and Neritic species in September, and of Neritic in August—as shown in Table II for that same year, on p. 316.

The more Oceanic or more Neritic character of the month in the three years (as determined by the percentage of Oceanic species at the foot of Table I in each case) is seen at a glance in the following table (50 per cent. is represented by a dash):—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1907...	—	N	N	N	N	N	—	O	O	N	O	O
1908...	O	O	O	N	N	—	O	N	N	N	N	O
1909...	O	N	N	N	N	N	—	N	N	N	N	O
N. =	0	2	2	3	3	2	0	2	2	3	2	0

If the numbers of Neritic occurrences be added up for each month, they show that mid-winter (December and January) and mid-summer (July) are more Oceanic in character than the intervening months, April, May and October being the most Neritic.

"Monotonic" Plankton.

Although many naturalists in the past have recorded the occurrence of dense crowds, "banks" or "swarms" of some one surface animal, or the members of one group, not merely round coasts but even in the open sea, Haeckel was the first, in 1890, to draw attention prominently to this important point in the distribution of the plankton, and to give it a distinctive name. In "Plankton-Studien," p. 57, he says:—"Die Zusammensetzung des Plankton aus verschiedenen Organismen ist sowohl in qualitativer als in quantitativer Beziehung sehr ungleichmässig, und ebenso ist die Vertheilung desselben im Ocean nach Ort und Zeit sehr ungleich; diese beiden Grundsätze gelten ebenso für das oceanische wie für das neritische Plankton." And further on, at p. 60, he distinguishes between "polymiktes" and "monotones" plankton, and says of the latter that this monotonic plankton shows a very homogeneous composition; and when a single prevailing species, genus or family forms more than three-fourths of the whole mass of the plankton, he regards it as a case of "uniform monotonic plankton."

Monotonic planktons are found frequently around the British Islands, and we have described some examples from the Irish Sea in the past. We desire to place on record a few additional cases, and to illustrate some of them by photo-micrographs* kindly prepared for us by our friend Mr. Edwin Thompson of Liverpool.

* These were originally made by Mr. Thompson in the Spring of 1909, and were shown as lantern illustrations to Professor Herdman's Evening Discourse before the British Association at Winnipeg in August. They have since been shown at the Royal Institution lectures (London), on "The Cultivation of the Sea," in January, 1910.

The Nauplius and Cypris stages (figs. 10 and 11) of *Balanus balanoides,* the common rock-barnacle at Port Erin, are sometimes found in dense swarms—the former in March and the latter about May.

Fig. 10.—Nauplius stage of *Balanus.*

Fig. 11.—Cypris stage of *Balanus.*

We have recently tried to determine the approximate number of nauplii set free in spring by the common *Balanus* living between tide-marks. This can be done by simply collecting barnacle-covered stones in March, laying them exposed to air in the laboratory, and after the lapse of a few hours separating the barnacles from the stones with the point of a knife and placing them in a vessel containing sea-water which has been kept in the workroom for a day. Very soon after the detached barnacles are placed in the sea-water it will be found that the nauplii are hatching out and swimming towards the

lighted side of the vessel. The water should be poured off at intervals through a fine silk sieve, which retains the nauplii and is afterwards washed into formalin. Fresh sea-water is added to the vessel and the process repeated from time to time. After twenty-four hours practically all the nauplii will have hatched. To get at the approximate number of nauplii produced by a single individual, take a definite number of barnacles, say ten, and collect all the nauplii till hatching ceases, then dilute the collection with water to a working volume and count the number of larvæ in several separate cubic centimetres drawn off from the well-shaken mixture with a wide pipette. The average of these samples is multiplied by the number of cubic centimetres representing the working volume, which gives the total nauplii present. The figures obtained are then divided by ten to give the approximate number of nauplii produced by each barnacle. This number varies with the size and age of the adult. We found from experiments that the large and probably full-grown adults yielded 9,000 nauplii, whereas half-grown ones produced only 3,600. If we take the average as 6,000, which is probably a low amount, and let this represent the number of nauplii produced by every barnacle along the coasts of Lancashire, Wales and the Isle of Man, it is clear that the zoo-plankton in a barnacle region must be subject to enormous but very temporary increases in the early spring by the advent of these larval forms.

The local abundance of adults on rocky coasts, such as Wales and the Isle of Man, must give rise to enormous swarms which have a very great influence on the volume of zoo-plankton in the neighbourhood. There can be no chance of a uniform distribution taking place over such an area as the Irish Sea, because, apart from the natural

mortality, there is the process of metamorphosis going on whereby the nauplius changes into the "cypris" stage, which settles down after a few weeks on the sea bottom as a young barnacle. The hatching period is probably a very short one and the nauplii are liberated from many barnacles at the same time. Unless the plankton is collected at the critical moment the swarming may therefore escape notice. A sample of plankton collected eight years ago in Barrow Channel consisted almost wholly of barnacle nauplii, and supplied us with enough material for use in the fishermen's classes until the spring of 1910. Although we have collected plankton every spring in the same locality and during the same period as in 1902, we have, so far, not again met with another swarm.

In the first part of this Report ('08, p. 186) we recorded a definitely localised swarm of Crab Zoeäs. These are cases of mero-planktonic organisms where the swarm is determined no doubt by the position and time of reproduction of the Neritic adult; but holoplanktonic and oceanic forms give equally good examples.

On Plate A, figs. 1 and 2 show "uniform monotonic" gatherings of the Dinoflagellate *Ceratium tripos* and of *Noctiluca miliaris*—the two most abundant causes of luminosity in the Irish Sea. *Ceratium* more usually occurs in quantity in the open sea round the Isle of Man, and *Noctiluca* along the coasts of Lancashire and North Wales. Both occur in greatest abundance in late summer or autumn. In September, '08, one of us found *Noctiluca* so plentiful at Piel, in the Barrow Channel, that estimations made by collecting bottles of the water and counting the *Noctiluca* showed that there were about 2,000,000 per gallon present.

The remaining two figures on Plate A show a monotonic Diatom plankton (fig. 3), consisting, however, of a

number of different genera and species, and for comparison with it a polymiktic plankton formed largely of Diatoms, but containing also Polychæt larvæ, Cirripede nauplii, and other animals. On Plate B all the figures show examples of uniform monotonic planktons, both plant and animal, the two upper being characteristic Diatom gatherings and the two lower being from hauls through swarms of Copepoda. Such Diatom gatherings are commonly found in April off Port Erin, and the Copepod swarms later in the summer.

We have several times found enormous but quite localised swarms of *Calanus helgolandicus* (Plate B, fig. 4) inside Port Erin Bay in July or August, and have filled jars with pure gatherings of this one species which have served to supply the University students with specimens of this typical large Copepod for several years. Large *Acartia* swarms like that from which fig. 3 was photographed have occurred late in April, in August and in September, and other common species of Copepoda have also occurred on occasions in large swarms, both in Port Erin Bay and in the open sea outside.

When we obtained 2,300 Sagitta in one haul of the shear net on March 31st, '09, that was undoubtedly an unusual swarm. The animal was not generally distributed through the neighbouring parts of the sea in that density, since a similar haul of the same net on the following day gave 245 specimens. We might quote many similar cases, but it seems unnecessary to multiply instances further. We may take as a final example pelagic fish eggs, in regard to which the statement has sometimes been made that they are uniformly distributed over very wide areas. Our experience certainly does not support such a view. The numbers obtained per haul are most irregular. Over large areas very few floating eggs may be obtained, even at

the spawning season, and then on occasions great numbers are found in the nets.

We have a record of a haul from the Lancashire Sea Fisheries steamer, at 18 miles N.W. by W. of Piel Gas Buoy, on 6. iii. 05, in which the plankton consisted of little else than fish eggs in quite unusual quantity. The net was taken in at intervals of ten minutes for an hour, but only the first sample was preserved, the other five gatherings being returned to the sea alive. The eggs, when examined, were found to be in all stages of development from the beginning of segmentation to the hatching point; and they included eggs of plaice, haddock, whiting, dab and flounder. Without doubt the majority of them would have hatched out in that immediate area.

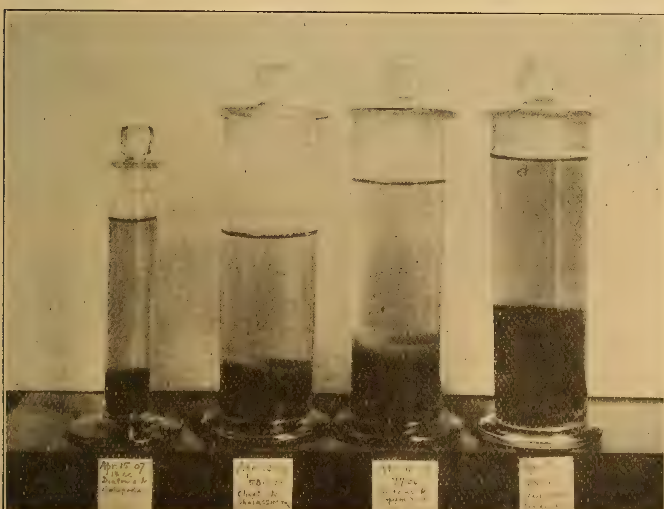


FIG. 12.—Monotonic Phytoplankton hauls, from April.

The four jars photographed in fig. 12 show hauls of very different volumes (13 to 100 c.c.) obtained with the same net at the same spot within 10 days in April, '07.

They are monotonic plankton hauls, such as are characteristic of the vernal phytoplankton maximum in the Irish Sea, and illustrate well the wide range in quantity obtained on neighbouring days at that season.

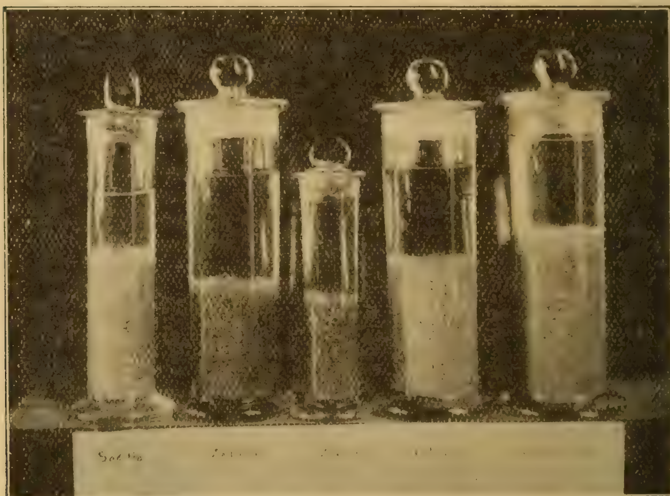


Fig. 13. Monotonic Zooplankton hauls, from August.

The five jars in fig. 13 show zoo-plankton hauls taken later in the summer with coarser nets, which had allowed the more minute organisms to escape. These, although not complete samples, are all notable cases of animals that were not generally distributed, but occurred in swarms so as to constitute a monotonic plankton.

The Food Supply of Marine Animals.

Most writers who have discussed the conditions of life in the sea have regarded marine animals as dependent directly or indirectly upon other animals and plants as organised food, and have considered them all as dependent

indirectly upon the plants, which would constitute, therefore, the ultimate source of organised foodstuff in the sea. In the long chain of dependent plants and animals the plankton has been looked upon as providing the first store of food, and, in fact, the phyto-plankton may be regarded as the primary transformer of the inorganic raw materials into the organic foodstuffs of the animals.

In '07, Pütter* claimed that the principal source of food was not to be found in the bodies of plants and animals, but in organic compounds dissolved in the water. The sea was to be regarded as a nutrient fluid in which, for example, organic carbon compounds were present in considerable quantity. This theory, if accepted, must be of great importance in any treatment of the metabolism of the ocean, and hence it must be considered here. Raben† and Henze‡ have shown quite recently that Pütter's estimate of the organic carbon compounds dissolved in sea-water was incorrect. Pütter, however, has lately ('09)§ published another work in which these corrections are accepted, without altering the essential points in his theory. It is unnecessary to review the whole work in detail here; but the subject may be considered under three heads:—

1. Do marine animals feed on solid food?
2. Is this food sufficient for their needs?
3. Is there more organic matter in solution in sea-water than is present in solid form (as plankton)?

There is no objection whatever, in the first place, to be brought against the view that marine animals may

* *Zeitschrift f. allgem. Physiologie.* Band VII, 2 and 3 Heft. 1907.

† *Wiss. Meeresunt. d. deut. Meere. Abteil. Kiel.* Neue Folge, Band II, 1909.

‡ *Henze. Pflügers Archiv. d. gesamte Physiologie, etc.* Bd. 123, 1908.

§ *Die Ernährung der Wassertiere.* Jena, 1909.

make use of nourishment in solution. The question is not, however, on what substances marine animals *can* feed, but on what they *do* feed under natural conditions. With regard to this first head, which is a biological question, most marine animals are known to take in some solid food, and the presence of an alimentary canal with digestive glands, the structure of appendages or other apparatus for catching food, and the habits of the animals, can only be satisfactorily explained on the assumption that solid food is necessary. Pütter, however, points out that it has often been very difficult, or even impossible, to trace any food matter in the alimentary canal or other internal cavities of aquatic animals, and finds it difficult to understand how crustacea living inside sponges can obtain solid food in the filtered water which reaches them. He also states (this will be referred to below) that the amount of solid food necessary for many marine animals is quite beyond their powers of catching. It must be remembered, however, that the absence of food in the alimentary canal is only negative evidence, and we know too little about the bionomics of many of these forms to draw far-reaching conclusions. It is possible, however, that the solid food may be insufficient in quantity to meet the demands of the animal. Pütter has calculated the amount of food required daily for several kinds of marine animals by measuring the quantity of oxygen used in 24 hours, and then knowing the composition of the plankton, the number of planktonic forms necessary for food can be calculated.

One of us* has shown that the alimentary canal of Copepoda contains diatoms, peridinians and flagellates. In fact, the chief food appears to be flagellates and small

* Dakin, "Notes on the Alimentary Canal and Food of the Copepoda," *Internationale Revue der gesamten Hydrobiologie und Hydrographie,* Bd. I, No. 6, 1. pp. 772-782.

diatoms. Pütter, however, states that the amount found in the alimentary canal is far too small, and that a *Calanus* (sp. not given) would require 9,750,000 *Thalassiosira nana* per day, if it depended on the plankton. The alimentary canal is, however, often found *full* of algal cells and débris, and we do not know how many times it can be filled and emptied in 24 hours. Allowing for this, however, it may still be impossible for a Copepod to obtain *sufficient* food in solid form if Pütter's estimations of the total amount required are correct. There are many other examples cited by Pütter representing the following groups: Protozoa, Porifera, Echinodermata, Coelenterata, Mollusca, Crustacea, Tunicata and Fishes; and if the figures given are correct, it is evident that food must be absorbed from the solution in sea-water. The balance of biological evidence is in favour of solid food being necessary, and hence it is only a question of an additional method of obtaining food, and not of a substitution of liquid for solid food. The amount of organic carbon dissolved in the sea-water was stated by Pütter in '07 to be 65 mg. per litre. Henze and Raben have brought this figure down to about 3-6 mg. per litre only. Allowing, however, for this great change, there still appears to be more carbon present in solution (in organic compounds) than in the plankton. It will be seen that the amount of organic carbon was considerably over-estimated, and it remains therefore for the figures showing daily food requirements to be carefully checked.

The plankton still remains as the primary food supply, for even if it is shown that the planktonic organisms are insufficient as food, the organic carbon compounds present in solution can be traced, as the products of metabolism, to the phyto-plankton which is their ultimate source.

Sunshine and Plankton.

As the view has frequently been expressed* that the great vernal maximum in phyto-plankton is due to the increase in sunlight at that time of year, it may be of interest to give the results of the daily record of the hours of sunshine made at the Port Erin Biological Station for the last three years. We have them recorded in tabular form for each day, but it will probably suffice to give here the totals for the months:—

	1907.	1908.	1909.	Average of 3 years.	Average of '08 and '09.
January	24¾	35	27	29	31
February	58	28½	57¼	48	43
March	113	83½	77¼	91¼	80½
April	69½	128¼	132¾	110¼	130½
May	103	179	198½	160¼	188¾
June	81	154½	160	131¾	157¼
July	143	111	122½	125½	116¾
August	103½	118	130½	117¼	124¼
September	121½	60	122	101¼	91
October	46¼	81	61	62¾	71
November	44	55¼	58½	52½	57
December	13½	21	39½	24½	30¼

As '07 may have been to some extent an abnormal year—the sunshine in April is less than in March, and in June is less than in any of the three following months—we have added in the right hand column of the table the monthly averages of the two years '08 and '09; and the curves in fig. 14 show these averages and those of the Bay plankton for the two years in question. The similarity in these two curves is considerable—both show the maximum in May, and a smaller but distinct elevation in August-September, the plankton curve appearing to follow that of the sunshine.

* *E.g.*, by Sir John Murray, and possibly by others before him.

If, now, we take the very different and possibly exceptional monthly distribution of sunshine in '07, and represent it as a curve (fig. 15) along with the curve of the monthly plankton of that year, we get the curious result of four sunshine elevations in March, May, July and September, and four plankton elevations in April, June, August and October. It is true that the highest sunshine peak is in July, and the highest plankton peak in April, but that difference in degree may be due to the

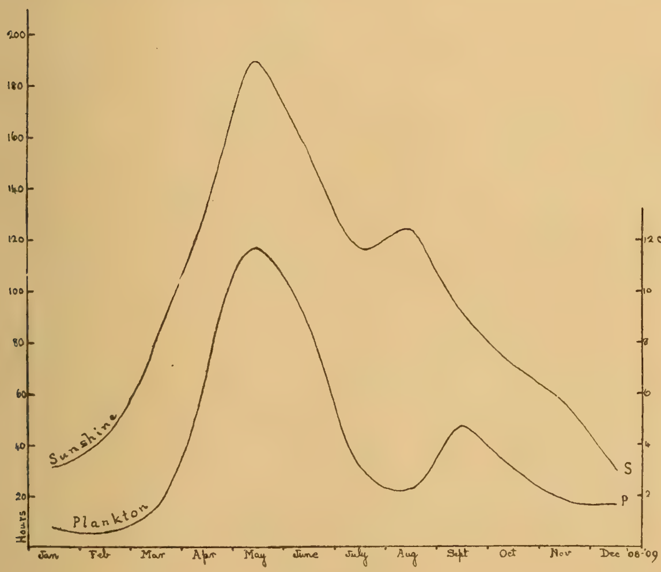


FIG. 14.

action of other factors, such as periodicity in life-histories and succession of species throughout the year; and after noting all differences, the curious correspondence between these two curves for '07 is remarkable, and it is the more striking when we remember that in the two years since ('08 and '09, fig. 14), when the distribution of sunshine showed a marked maximum in May, the plankton

maximum was also in that month; so that, in fact, as the figures show, each of the two very different sunshine curves is followed by a closely similar plankton curve.

With the view of testing whether there seemed to be any correspondence between the sunshine day by day and the plankton, especially the surface phyto-plankton, exposures were made with Wynne's "Actinometer"

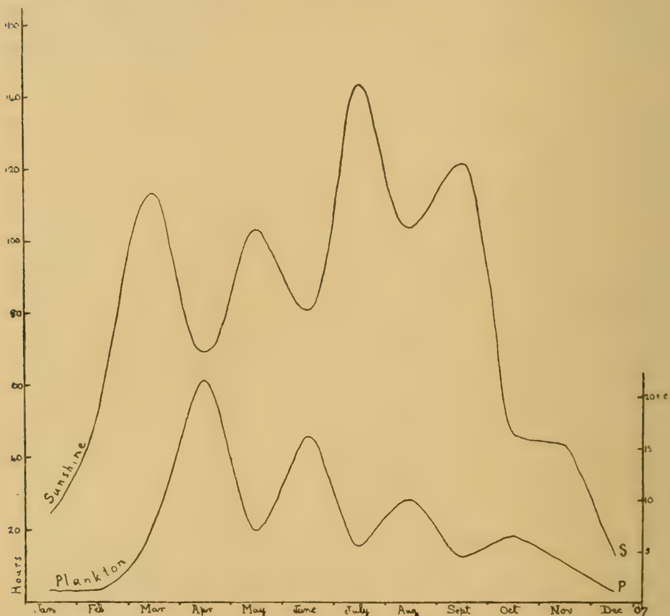


FIG. 15.

on every possible occasion in the Easter vacation, '09. Between March 29th and April 26th the actinometer readings varied from two seconds on April 9th (bright sunshine and a clear sky) to 13·5 seconds on March 31st (sky overcast, no sun visible). The actinometer reading was generally taken on the way out to sea, half-an-hour or so before the plankton nets were hauled. Frequently a second reading was taken on the return journey, and

the two generally agreed closely. Although there does not seem to be any connection between the plankton catches and the daily variations in the actinometer, still there does seem to be a relation between the marked rise in all the plankton nets on April 13th and the permanent increase in the amount of sunlight which set in a week before. On April 5th the actinometer reading was 12·5 seconds, on April 6th it was 3·5, and from that time till the end of the month it ranged only between 2 and 6 seconds, and the average for the week preceding the great increase in plankton was 3·3 seconds, while for the week previous to that (March 30th to April 5th) the average of the actinometer readings was 9·9 seconds. The threefold increase in the sunlight from 9·9 to 3·3 seconds was followed after a week by an eight-fold increase of the surface phyto-plankton (from about 100,000 to about 800,000 Diatoms per haul). This actinometer series of observations tends to confirm the correspondence between total hours of sunshine and the volume of the plankton noted above.

During this period the sea-temperature (surface) did not vary much, the curve being a great contrast to that of the sunshine. In the month from March 27th to April 26th the temperature of the water rose only 1 degree Centigrade, from 7·1° C. to 8·1° C.; and during the four days from April 5th to 9th, when the sunshine record increased from 12·5 seconds to 2 seconds (by the actinometer), the sea-temperature increased only from 7·075° to 7·9° C., and the average of the five observations on these days is 7·555° C. It is clear, then, that change in temperature will not account for the sudden increase in the plankton which seems to have begun on April 9th or 10th —after five days of increased sunshine.

The present year seems to have shown an unusual

amount of sunshine in April and May, and possibly the increase of plankton in June over '08 may be due to that cause.

This is probably the best place to show (fig. 16) the weekly variations in the temperature of sea and air in Port Erin Bay, as recorded at the Biological Station. For comparison we give also the diagram (fig. 17) printed in last Report, showing the temperature variations in '08. We have not a diagram for '07, but we have the series of weekly records corresponding to those of '08 and '09. It will be seen that this year ('09) the air-temperature whole line, in place of crossing the dotted line representing the sea-temperatures at one point (the first week in May in both '07 and '08), nearly reaches it at the end of March, crosses it early in April and back again at the end of the month, gets above it again in the beginning of May, and dips under and up again for the last time in the middle of that month. After that there is less difference between the temperature of sea and air during the summer than in the previous year, and the air-temperature reaches 58° F. only, in place of 61°, but remains above the sea longer in autumn, to August 21st in place of August 5th in '08.

Vertical Hauls.

The two vertical closing nets we have had in most frequent use during the three years are called briefly the "Hensen" and the "Nansen." The "Hensen" was obtained from Kiel, and is a quantitative net of the same size as the "Medium Apstein," but provided with two brass semi-circular flaps at the mouth, so that it can be closed at any depth by the action of a "messenger" sent down the line. Strictly speaking, it is the "Petersen-Hensen" net, but that name is too long for every-day use

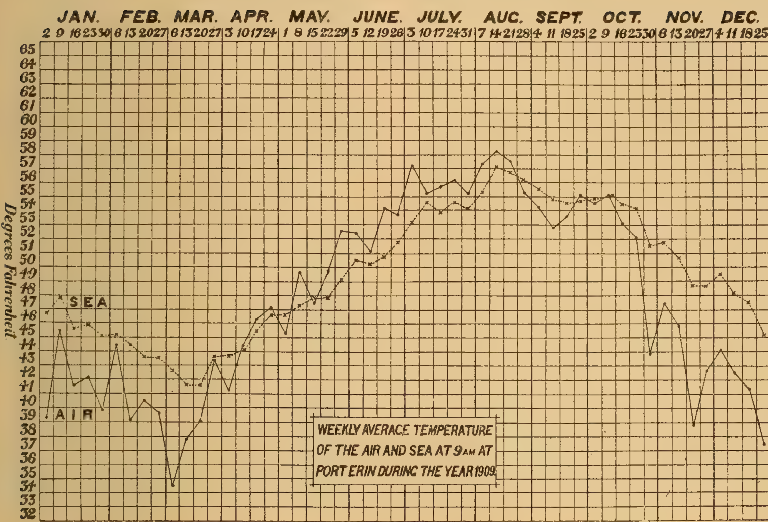

JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
Degrees Fahrenheit.
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 AM AT PORT ERIN DURING THE YEAR 1909.

FIG. 16

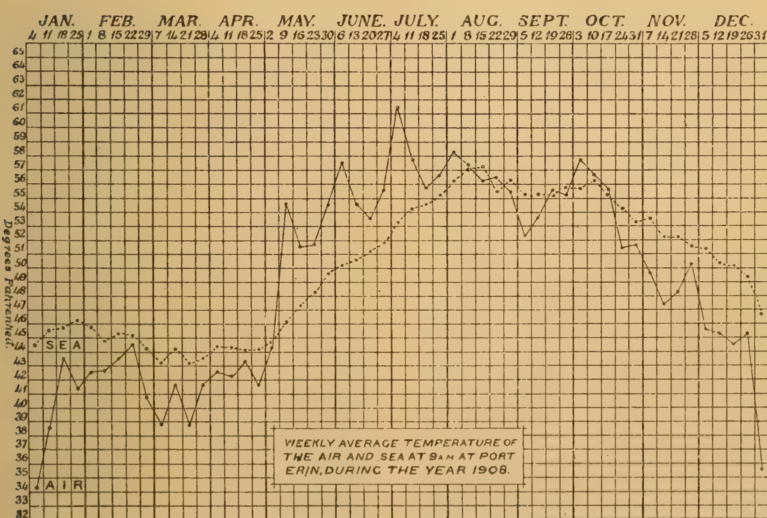

JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
Degrees Fahrenheit.
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A M AT PORT ERIN, DURING THE YEAR 1908.

FIG. 17.

on board ship. The "Nansen" net is the smallest of the three sizes made at the Central Laboratory in Christiania, and has a mouth of 35 cm. in diameter. We also have on the yacht the largest size, measuring 100 cm. across, but it is the smaller size that is meant when the word "Nansen" alone is used in this Report. This net is also closed by the action of a brass messenger running down the line.

Our Hensen and Nansen nets are both made of No. 20 silk, but are not strictly comparable, because of differences in shape and size. As a rule the Nansen catches more than the Hensen does. The two sets of catches are therefore treated separately in what follows:—

Hensen Net Hauls in 20 to 10 fathoms.

In the three years ('07-'09) our closing modification of the Hensen quantitative net has been used in all 231 times, and of these 141 represent gatherings made vertically in the zone of 20-10 faths.

Stat. I, 5 miles off Bradda Head, is the locality where the greatest number of hauls was taken in each of the years (18 in '07, 28 in '08, and 26 in '09, and where, therefore, a comparison may most naturally be made.

Station I.	Easter.		
	No. of Hauls.	Range in c.c.	Average Catch.
1907	12	0·5 to 9·5	3·2
1908	11	0·1 „ 1·3	0·5
1909	19	0·15 „ 3·5	1·1

Station I.	Summer.		
	No. of Hauls.	Range in c.c.	Average Catch.
1907	6	0·05 to 0·75	0·4
1908	17	0·1 „ 1·5	0·7
1909	7	0·3 „ 0·8	0·5

FIG. 1. Peridinian Plankton, consisting mainly of *Ceratium tripos*.

FIG. 2. Plankton, consisting almost wholly of *Noctiluca miliaris*.

FIG. 3. Diatom Plankton, consisting mainly of *Coscinodiscus* and *Biddulphia*.

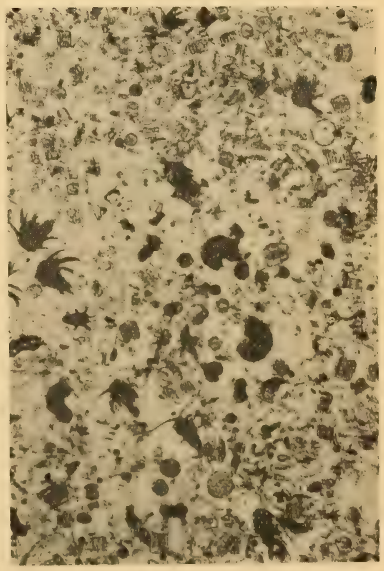


FIG. 4. Mixed Plankton, consisting of *Diatoms*, *Nauplii*, *Polychaet larvae*, &c.

Fig. 1. Diatom Plankton, consisting mainly of *Rhizosolenia semispina*.

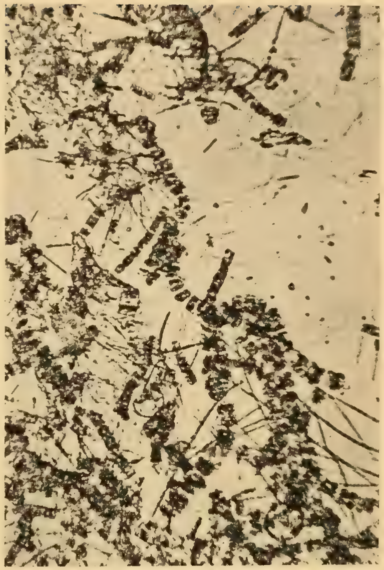


Fig. 2 Diatom Plankton, consisting mainly of *Thalassiosira nordenskioldii*.

Fig. 3. Copepod Plankton, consisting mainly of *Acartia discaudata*. One *Temora* is seen.

Fig. 4. Copepod Plankton, consisting wholly of *Calanus helgolandicus*.

We have already shown that some unusually large catches were made in the spring of '07, and if we omit that period then the remaining averages range from 0·4 to 1·1 c.c. In fact, if three exceptional hauls at the beginning of April, '07, be left out of account, that year would come into range with the others, and the normal catch for this net, pulled through these 10 faths. of water, in April and August together, would then appear to be about three-quarters of a cubic centimetre. The average for April is rather higher than that for August.

In looking at the details of the numbers of Diatoms, Dinoflagellates and Copepoda (to take only the main groups) for all the Hensen net hauls (all stations) in the three years, one notices far larger quantities of Diatoms (amounting to millions on several occasions) and Dinoflagellates (a few thousands) in the earlier part of April in '07 than in the corresponding period of the other two years; while again, in '09, the phytoplankton was more abundant in the latter part of April than at that time in the previous two years; but apart from this, there is considerable similarity in the three series. The Copepoda (adults, juveniles and nauplii) especially show substantial agreement. In August the Dinoflagellates are distinctly more abundant in the '08 hauls than in the other two years.

Nansen Net Hauls in 20 to 10 fathoms.

In the three years ('07-'09) the Nansen closing net, of 35 cm. diameter at mouth, and made of No. 20 silk, has been used in all 266 times, and of these 141 represent gatherings made vertically in the zone of 20-10 faths., the same number as in the case of the Hensen net.

At Stat. I, in all, 73 hauls were taken (20 in '07, 28 in '08, and 25 in '09) with the results given here;—

Station I.	Easter.		
	No. of Hauls.	Range in c.c.	Average Catch.
1907	13	2·0 to 77·0	23·2
1908	11	0·1 „ 8·0	2·0
1909	19	0·4 „ 18·7	2·9

Station I.	Summer.		
	No. of Hauls.	Range in c.c.	Average Catch.
1907	7	0·5 to 4·0	1·7
1908	17	0·1 „ 1·0	0·5
1909	6	0·3 „ 1·0	0·6

Nearly all these results are larger than those obtained with the Hensen net, and the amount credited to Easter, '07, is surprisingly greater than all the others. That figure depends, however, upon a few quite exceptional hauls obtained at the time of the Diatom maximum. If we omit that period the remaining averages range from 0·5 to 2·9. The average of this net for April is about 2·5, and for August about 0·9. For April and summer together the average is about 1·7, as against about 0·7 for the Hensen net.

The remarks made as to the distribution of the Diatoms, Dinoflagellates and Copepoda throughout the years under the Hensen net apply here also. The Diatoms rise to 17 millions twice, as against 2½ millions in the Hensen net, and the Dinoflagellates to 37 thousand against 2 thousand in the Hensen. In '09 the Dinoflagellates reach 20 thousand in April, while in '08 the highest point is 3,600. The Copepoda, like most other groups, are fewer per haul in '08 than in '07 and '09.

If it is questionable whether the results of the Hensen and Nansen nets are strictly comparable, it is

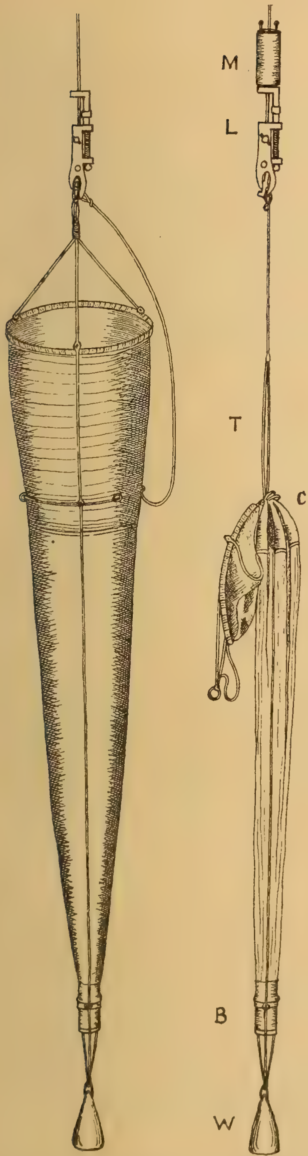


FIG. 18.—Nansen Net: at left hand when fishing; at right hand being hauled up, closed. B, brass bucket; C, canvas front to net; L, releasing apparatus actuated by M, messenger running on line; T, throttling noose constricting net; W, weight.

still more doubtful whether these vertical hauls can be brought into relation with those of the horizontal surface tow-nets. However, we add here (p. 338) another table of Easter and Summer results at Stat. I, in the three years, taken from the records of the "fine surface" net. This net has nearly the same diameter of opening as the vertical nets, and is made of the same No. 20 silk. It is towed for 15 minutes while the vessel is going "dead slow," and probably passes through about a quarter of a mile of sea. Whether a column of water a quarter of a mile in length is strained through the net is quite another matter, and it is practically certain to be less, but how much less is very doubtful.

Looking at these figures along with those of the Nansen net, and omitting Easter, '07, we find that the two series are not very different, and that the surface net, as might be expected, gives, on the whole, larger catches. It certainly strains a larger volume of water, and that it

does not show a proportionately still larger catch than it does must be due to the fact that a large proportion of the organisms in the sea are not at the surface, but some way below. We have given elsewhere evidence that the most populous zone is really above the part strained by these vertical nets (20 to 10 faths.), but the water just below and about 10 faths., sampled by the Nansen net, is probably on many occasions richer in organisms than the top few feet through which the surface net is hauled.

Station I.	Easter.		
	No. of Hauls.	Range in c.c.	Average Catch.
1907	24	2·5 to 20·5	11·8
1908	23	0·5 „ 6·0	2·2
1909	19	0·5 „ 10·7	3·9

Station I.	Summer.		
	No. of Hauls	Range in c.c.	Average Catch.
1907	21	1·0 to 7·5	2·7
1908	30	0·2 „ 7·5	1·0
1909	7	0·1 „ 2·0	0·6

Some Vertical Hauls in Deeper Water.

We have a series of five dates, two on adjoining days in April and three early in August, when series of vertical hauls were taken at a station in mid-channel with closing nets, at specified zones of depth between 60 faths. and the surface.

The more important results are shown in the following table :—

1909.	Zone.	Diatoms.	Dino-flagellates.	Copepoda. Adults.	Copepoda. Nauplii.
April 7 ...	60-40	10,525	100	10	300
	40-20	14,521	130	20	320
Hensen	20-10	14,235	380	26	560
	60-0	19,260	365	141	720
April 8 ...	60-40	12,475	300	35	750
	40-20	62,120	1,500	142	3,600
Hensen	20-10	20,420	640	91	2,000
	60-0	86,250	1,600	115	4,900
Aug. 6 ...	60-40	180	230	254	410
	40-20	100	60	195	390
Nansen	20-10	110	10	270	1,140
	10-0	80	—	291	1,190
Aug. 7 ...	60-40	35	10	116	235
	40-20	40	5	85	50
Nansen	20-10	50	25	32	190
	10-0	180	30	1,900	480
Aug. 10 ...	60-40	440	30	230	440
	40-20	545	40	282	165
Nansen	20-10	735	40	267	570
	10-0	120	60	1,928	2,510

On April 7th, in addition to a vertical haul from bottom (60 faths.) to surface, hauls with the Petersen-Hensen closing net were taken through the zones 60-40, 40-20 and 20-10, but no vertical haul was taken in 10-0 faths. The figures show in every case some increase in numbers in passing upwards towards the surface, and the zone 20-10 contains the largest population. It will be noticed that this zone is only 10 faths., half the extent of haul in the two deeper zones.

On April 8th the hauls were the same, but the highest numbers are now in the middle zone, 40-20 faths., and next comes the upper zone. The lowest zone, as on the previous day, contains least life. In August an additional vertical haul through the most superficial zone, 10-0 faths., was always taken. On August 6th the plankton is fairly well distributed through the layers.

On August 7th there is a well-marked increase upwards, so that most of the plankton comes to be in the zone 10-0 faths. Finally, on August 10th, with the exception of the Diatoms, there is again an increase upwards, and most of the organisms are, as in most other cases, in the top 10 faths. This supports the conclusion we arrived at in the first part of this Report ('08, p. 130), that the most populous zone in the Irish Sea is below the surface but above 10 faths., and is in some cases between 5 and 10 faths.

Limitations of Vertical Hauls.

Beyond the above general conclusions as to the average catch, and as to the proportionate representation of the chief groups in the different seasons and zones of depth, we do not consider it possible to go. For the purpose of testing the reliability of the evidence given by the vertical closing nets in regard to further details, viz., the numbers and distribution of species, we have, in the first instance, made a careful examination of certain pairs of hauls made through the same distance, in exactly the same way, at the same spot and within a few minutes of each other. During the three years 14 such double hauls have been made. In no case did the two nets contain exactly the same species, in one case as many as ten species present in one haul being unrepresented in the other. This was on August 7th, '09, in mid-channel, about 13 miles from land, the net being the Nansen hauled from 20 to 10 faths. The species were:—*Chætoceros teres*, *C. criophilum*, *Coscinodiscus radiatus*, *Rhizosolenia shrubsolei*, *Ceratium fusus*, *C. tripos*, *Peridinium sp.*, larval *Polychæta*, *Acartia clausi*, and *Microcalanus pusillus*.

Again, the species represented in both hauls of a pair are often present in very different numbers. For example, on August 6th, '09, at the mid-channel station, when the Nansen net was hauled twice from 60 faths. to the surface, one haul had 6,420 Copepod nauplii, the other only 300. On August 7th, '09, at the same place, with the Nansen net hauled through 60-40 faths., one haul had 15 *Oithona* and 17 *Microcalanus*, while the other had 2 and 1 respectively. On August 17th, '08, in mid-channel, when the Nansen net was hauled from 60 faths. to the surface, one net had 6,250 *Ceratium furca*, the other only 750. It is thus evident that, even leaving out of the question organisms too small to be retained by the net, a given vertical haul cannot be regarded as necessarily offering a true picture either of the number of species present or of their relative amounts.

Further evidence of this may be got from considering the following series of hauls through different depths, using the same net:—

On April 24th, '08, at Stat. I, the Nansen net hauled from 20 to 10 faths. contained 11 species not present in the same net hauled from 20 faths. to the surface (e.g., 500 *Ceratium tripos*), and of the 19 species common to both, the net hauled through 20-10 faths. had the larger numbers in 15 cases, e.g., 30,000 *Chœtoceros sociale* to 250, and 20,000 *Chœtoceros teres* to 1,200.

On September 14th, '08, at Stat. IV, the Nansen net was hauled from 10 to 5 faths., and from 10 faths. to the surface. The 10-5 faths. catch had 9 species not present in the other, and had more of all the species common to the two except in the case of *Oikopleura*.

On August 7th, '09, in mid-channel, the following hauls were made with the Nansen net:—10-0 faths. (twice), 20-10 faths. (twice), 40-20 faths. (twice), 60-40

faths. (twice), 69-0 faths., and 73-0 faths. *Coscinodiscus concinnus* occurred only in the 69-0 faths. haul; *Guinardia flaccida* only in one 60-40 faths. haul; *Lauderia borealis* only in the 73-0 faths.; *Ceratium furca* in one 60-40 faths., and one 40-20 faths.; *Trochiscia sp.* only in one 20-10 faths. haul.

On another occasion, when hauls were made at varying depths from 60 to 10 faths., and one from 60 faths. to the surface, *Oikopleura* was present in all the hauls up to 10 faths., but absent from the haul from 60 faths. to the surface.

We have also observed how frequently the pictures presented by the Hensen and Nansen nets differ, with regard both to the number of species present and to their vertical distribution. Thus, on April 8th, '09, at the mid-channel station, the Hensen and the Nansen nets were hauled as follows:—60-40 faths., 40-20 faths., 20-10 faths., and 60-0 faths. *Coscinodiscus grani* was present in the Hensen net in the 60-0 faths. haul only, and with this evidence alone one would say it was present only in the upper layers. But in the Nansen net it occurred in the 60-40 faths. haul only, thus giving grounds for supposing that it was fairly uniformly distributed, but had escaped the other hauls. On several occasions, when the Hensen and Nansen nets have been worked together, one of them has had species not represented in the other.

Further, when the vertical nets are hauled to the surface, it is often advisable to check their results by comparing with the surface nets. Thus, on September 14th, '08, at Stat. IV, both Hensen and Nansen nets hauled to the surface had missed the following species:—*Chætoceros contortum*, *Rhizosolenia shrubsolei*, *R. stolterfothi*, "*Mitraria*," *Podon intermedium*, *Anomalocera pattersoni* and *Microcalanus pusillus*. This was observed

on several other occasions, and shows that the vertical closing nets, even when more than one haul is made, may miss many of the species present. These various examples will suffice to show that vertical hauls do not give such truly representative samples as has sometimes been supposed, that results taken from a few hauls only may be deceptive, and that it is advisable to check the accuracy by taking duplicate observations whenever possible.

Necessity for Frequent Vertical Hauls.

It has sometimes been said that if vertical hauls be taken from the bottom to the surface, they are bound to show everything that is present in the area, and to represent each constituent of the plankton in its true proportion. It has been argued that while the surface plankton may vary greatly, and therefore the surface nets may give partial or deceptive samples, the various groups of the plankton, however much they may rise or fall or segregate into zones, *must* always be somewhere between the bottom and the surface, and therefore must all be sampled by a vertical haul. That may be the case in many localities, but it is not necessarily the case always. It must be remembered that some groups of organisms move not merely up and down, but also laterally, so as to reach and occupy some narrow gulley or some deeper hole, and in that case a vertical haul might capture that particular group of organisms or might escape doing so, and even a small series of vertical hauls might, through this segregation, which is horizontal as well as vertical, give quite a deceptive impression of the constitution of the plankton. This possibility is exemplified in the accompanying diagram, which represents a section across a fjord or sea-loch with an irregular bottom having a ridge at R, a

deeper gulley at D, which descends to over 50 faths., and a shallower area at S. If we suppose that, as is actually the case in many localities, such Copepoda as *Calanus helgolandicus* or *Euchæta norvegica* are at certain times of the year confined to the deep water below 50 faths., then they would occupy the shaded area at D which is below about two-fifths of the surface of the water, and in volume is about one-fifth of the whole. If four equidistant vertical hauls (1, 2, 3 and 4) are taken across the loch, these Copepoda (say, *Calanus*) will appear in one quarter of the samples, and if vertical hauls 1 and 2 only are taken *Calanus* will appear in one half of the material, while if hauls 2, 3 and 4 are taken no samples of *Calanus* will be

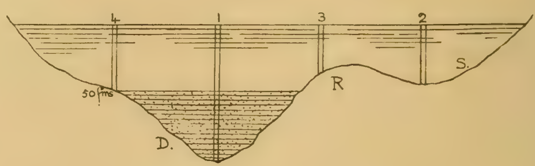


FIG. 19. Diagram showing diverse vertical hauls.

obtained. In every one of these cases, if the haul or hauls were taken as representative of the whole area, the result obtained would be erroneous. The real distribution in this case is that *Calanus* occupies one-fifth of the whole mass of the water; but if one considered only the number of square metres underneath which vertical hauls showed *Calanus*, the conclusion arrived at would be two-fifths, twice too much. If haul 1 only were examined, it might be thought that *Calanus* was universally present, if haul 3 that it was absent, and if hauls 1 and 2 that it was present in half the water, much too large a result—the conclusion being that results obtained from few and distant hauls are liable to be deceptive.

Comparison of Nets.

It may be worth while to attempt to arrive at some estimate of the catching power of each net by considering all the evidence obtained in three years as to the performances of the different nets at the different stations. We shall not take the time of year into account, but as we have some evidence that the years differed in character, we shall in the first instance keep these distinct; it is easy to combine them afterwards if wished. We shall give, then, one figure per net at each locality in each year. For example, we find that the Nansen net was used in 20-10 faths., at Stat. I, 25 times in '09, and the average catch was 2·3 c.c., and the average for all stations (49 hauls) in that year was 2·4 c.c.—a fairly close agreement.

It is doubtful whether these figures will help us much in forming a true picture of the performances of the nets, except possibly in the totals based on a considerable number of hauls. Looking at the averages for all stations in each year, as shown in the right hand column, it is clear that, as we have pointed out before, the exceptionally large hauls in April, '07, have raised the figures for that year unduly. On the other hand, the catches in '08 were possibly abnormally small. Those for '09 or an intermediate series between those for '08 and '09, would probably be the best approximation to the usual catching power of the net in these seas, and under the conditions employed. Thus the figure for the Hensen net would be about 1 c.c., for the Nansen nearly 2, for the weight net and the fine surface net nearly 3, and for the corresponding net with a coarser mesh about 5. We have placed the number for the larger nets in a table by themselves, as they are clearly not comparable with the

1907.	Stat. I.		Stat. II.		Stat. III.		Stat. IV.		Stat. V.		Bay.		Totals.	
Net.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.
Hensen (20-10 fms.)	18	2·2	10	8·8	6	22·4	2	0·8	11	1·1	—	—	47	5·8
Nansen (20-10 fms.)	20	15·6	9	22·6	5	47·6	2	0·5	11	1·8	—	—	47	16·5
Weight	24	12·5	12	14·6	13	15·8	6	9·1	11	10·9	—	—	66	12·9
Surf. fine	47	7·6	21	10·7	37	11·08	14	4·6	25	6·03	111	9·15	255	8·7
Totals	109	9·2	52	13·3	61	16·2	24	5·07	58	5·2	111	9·15	415	9·9

1908.	Stat. I.		Stat. II.		Stat. III.		Stat. IV.		Stat. V.		Bay.		Totals.	
Net.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.
Hensen (20-10 fms.)	28	0·6	6	0·65	1	0·8	—	—	2	0·4	—	—	37	0·6
Nansen (20-10 fms.)	28	1·08	6	1·4	1	1·2	—	—	2	0·5	—	—	37	1·1
Weight	27	2·2	7	1·9	23	3·5	2	1·0	3	3·9	4	0·65	66	2·6
Surf. fine	51	1·5	12	1·45	44	2·4	3	1·1	6	3·5	105	3·6	221	2·7
,, coarse	7	4·3	4	2·5	7	5·8	1	7·0	—	—	46	5·2	65	5·03
,, "pulley" ...	10	2·1	1	2·5	5	2·5	—	—	—	—	—	—	16	2·3
Totals	151	1·5	36	1·5	81	2·9	6	2·05	13	2·6	155	3·9	442	2·7

1909.	Stat. I.		Stat. II.		Stat. III.		Stat. IV.		Stat. V.		Bay.		Totals.	
Net.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.
Hensen (20-10 fms.)	26	0·9	1	0·3	24	2·05	—	—	—	—	—	—	51	1·4
Nansen (20-10 fms.)	25	2·3	1	0·5	23	2·6	—	—	—	—	—	—	49	2·4
Weight	26	3·1	1	3·0	27	3·5	2	1·1	1	0·1	1	0·8	58	3·1
Surf. fine (funnel) ...	26	3·03	1	2·5	27	3·5	3	1·0	1	0·05	2	2·3	60	3·07
,, ,, (open) ...	14	1·3	—	—	15	1·5	—	—	—	—	113	2·6	142	2·35
,, coarse	25	5·1	—	—	26	6·5	2	5·0	1	0·35	113	5·6	167	5·63
,, otter	26	2·4	1	1·8	26	2·9	1	0·5	1	0·1	—	—	55	2·6
Totals	168	2·7	5	1·6	168	3·3	8	1·9	4	0·15	229	4·06	582	3·3

Net.	STAT. I.		STAT. II.		STAT. III.		STAT. IV.		STAT. V.		TOTALS.	
	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.	No. of hauls.	Average catch per haul in c.c.
Shear, '07	3	31·5	3	13·2	8	37·5	5	43·4	1	30·5	20	34·07
,, '08	10	35·3	1	13·0	13	15·8	3	38·0	1	36·0	28	25·8
,, '09	2	23·5	—	—	7	41·4	—	—	—	—	9	37·4
Yngel, '08	—	—	1	84·0	3	56·2	—	—	—	—	4	63·1
Large Nansen, '09 ...	5	13·6	—	—	—	—	1	50·0	—	—	6	19·6

others. It is seen that the shear net is fairly constant throughout the three years, with a value of about 26 to 37. The number for the Yngel trawl is about twice that; but the hauls of the Yngel and the large Nansen have been as yet too few to lead to any sure conclusions.

Effect of the Propeller on Nets at Stern.

In Part II of this Report, last year, we alluded to the criticism that had been made by Professor Kofoid (and possibly by others since) that the effect of the steamer's propeller in mixing up water of different levels might account for the differences that we sometimes found between the catches of two similar surface nets towed over the stern. After stating the conditions of the case last year, we continued: "these are all points that ought to be cleared up by experiment, and we propose to deal with them in the coming season, and to compare, for example, the catches in nets towed some little way off the side of the ship with similar nets towed behind."

During the past year we have carried out this intention; and we have now a long series of observations made under similar conditions at two different times of year, April and August. We attached one of the two exactly similar surface nets to an otter-board which was towed from a position forward of the foremast on the starboard side, so as to carry it out about 20 feet from the side of the boat amidships. The other net was in the usual position over the stern. If there were any force in the criticism, the "otter-net," which was certainly sampling surface water quite undisturbed by the propeller, or any other part of the ship, ought to give results differing from those obtained from the net at the stern in water which might be supposed to be affected by the action of the propeller; but no such difference is to be seen. In 44 hauls of each net, taken in April, '09, the

average catch for the otter net is 3·53 c.c., and for the stern net 4·30 c.c. Out of the 44 double hauls, the amount of the catch in the two nets does not differ by more than 0·5 c.c. in 19 cases, in 8 of which it differs by not more than 0·2 c.c. In 16 cases the catches differ by 1 c.c. or over. The average difference is 0·76 c.c.

In 27 cases out of the 44 the stern net caught more than the otter net, in 13 the reverse was the case, and in 4 pairs of hauls the catches made by the two nets were equal. As examples of cases where two very different hauls were made (just as was sometimes the case with two nets at the stern), the stern net caught 8·5 c.c. and the otter only 2·2 c.c.; and again, the stern net caught 9·4 c.c. and the otter 4·5 c.c. In fact, it is obvious that the otter net gave the same kind of catch as it would have done if it had been placed beside its fellow at the stern.

As a further test, however, we propose this coming season to use two otter-nets, one on each side of the ship, for comparison both with the stern nets and with one another. If any difference shown between the two otter-nets is as great as the difference between the stern nets, it is clear that the variations are real and not due to any supposed action of the propeller or other influence of the ship.

As to the organisms present, in five cases the catches are remarkably similar. As an example, take April 22nd, Stat. III:—

	Total Catch.	Diatoms.	Dinofl.	Copepoda.
Otter	7·2 c.c.	513,650	9,500	61
Stern	6·8	515,050	3,400	70
Weight	7	568,200	1,500	105

	Echin. larvæ.	Copep. Naupl.	Oikopleura.
Otter	100	900	400
Stern	100	800	400
Weight	100	500	910

Here in contrast is an example of two very dissimilar hauls taken on April 9th at Stat. III :—

	Total Catch.	Diatoms.	Dinofl.	Copepoda.	Polychæt larvæ.
Otter	0·8 c.c.	21,425	600	4	0
Stern	1·2	43,800	250	15	100
Weight	1·6	20,000	3,800	218	800

	Echin. larvæ.	Copep. Naupl.	Oiko-. pleura.	Fish Eggs.
Otter	20	200	1	54
Stern	1,000	500	50	19
Weight	2,000	7,800	800	2

We give also an example of a case where, although the two nets caught the same quantity, the catch was made up of very different organisms, viz., April 2nd, Stat. III :—

	Total Catch.	Diatoms.	Dinofl.	Copepoda.	Polychæt larvæ.
Otter	4 c.c.	139,000	2,750	1,316	750
Stern	4	116,750	4,000	2,511	1,000
Weight	4·7	147,750	2,550	2,790	1,500

	Echin. larvae.	Copep. Naupl.	Oiko- pleura.	Fish Eggs.
Otter	750	9,000	530	4
Stern	500	14,000	1,000	3
Weight	250	5,000	1,100	5

In most cases the similar net, used at the same time, with a weight attached so as to keep it a few fathoms below the surface, gave rather a larger haul. We have

added the figures for the "weight" net in each of the three examples above for comparison with the two surface nets.

The August hauls give us practically the same results. There were 16 double hauls, and if we omit one that seems very exceptional in character, in 5 of these the otter net had the largest catch, in 5 the stern net caught more, and in the remaining 5 cases the catches were equal. The average catch for the otter net is 0·27 c.c., and for the stern net 0·30 c.c., while for the weight net, worked at the same time in a deeper zone, the average is 0·35 c.c.

Comparison of "Funnel" with Wide-mouthed Net.

As a further development of the experiments with the "Pulley-net" described in last year's Report, we added, in '09, canvas inverted funnels in front of most of our nets in order to limit the intake of water, and consequently the pressure on the net. The inverted funnel, suspended by its narrower end and joining the ring of the tow-net by its wider, reduced the opening of the net from 14 to 5 inches. As various opinions had been expressed as to what the result of thus reducing the mouth of the net would be, one of the older type of simple open-mouthed tow-nets was used constantly as a surface net alongside the funnel net, with the result that the latter invariably caught more, and frequently a great deal more—up to 12 times as much. The average of 30 double hauls gives 1·52 c.c. for the open net, and 4·36 c.c. for the funnel net—one to three nearly. Having satisfied ourselves that restricting the opening by means of the canvas funnel leads to a greater, that is a more representative, catch, we shall in future use funnels with all our surface tow-nets.

The criticism has also been made at the International Council, we are told, that our two exactly similar surface nets fishing at the same time and catching somewhat different gatherings were probably one on the windward and the other on the leeward side of the ship working under very different conditions, and so could not be expected to yield comparable results. We can at once remove that objection by stating that that is not the case. When working the surface nets the ship is put head to wind and steams very slowly against any wind there may be; so there is no windward side, and the two nets in question are worked from the stern, side-by-side, and are, so far as can be ascertained, under similar conditions.

Old and New Nets.

In the last part of this Report we showed how rapidly the meshes of the fine No. 20 silk became clogged,

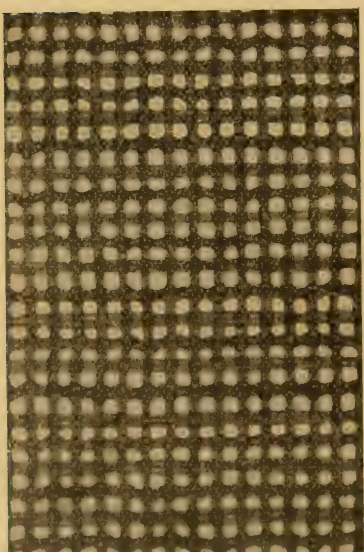


Fig. 20. Mesh of No. 20 silk when new, × 23.

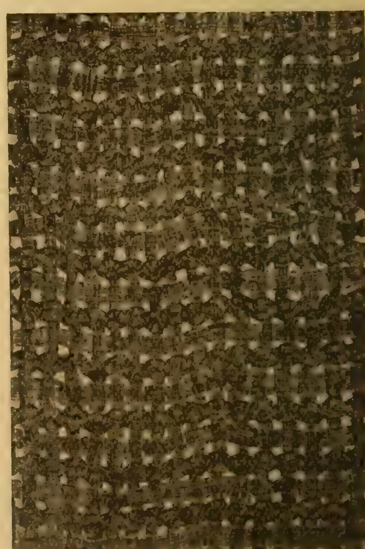


Fig. 21. Mesh of same silk after use in Nansen net for some months, × 23.

and how the catching power of a new net diminished from day to day. We figure here photographs, which have been kindly taken for us through the microscope by Mr. Edwin Thompson, of (fig. 20) the silk of a new net before being used, and (fig. 21) with the same magnification a piece of silk from an old net that had been used for some months. The flattened and swollen condition of the fibres, the distortion and reduction in size of the meshes, and the absolute closing up of some of them is obvious, and accounts clearly for the reduced straining power of the net.

CONCLUSIONS.

In the two preceding parts of this Report we have drawn certain conclusions, some of which may now be re-stated, and revised where necessary, in the light of the third year's work.

Total Plankton.—The most remarkable feature of the distribution of the total plankton throughout the year is the great increase in spring, due mainly to the sudden appearance of enormous quantities of Diatoms. This year the vernal maximum was later than in the two previous years. It extended from April far into May, and died off suddenly between the 24th and the 28th of May.

There is usually a second less marked and less constant increase in the plankton in September-October. It is largely composed of Copepoda, although some Diatoms, and on occasions Dinoflagellates in quantity, may also be present. There may be lesser elevations in June and August, due sometimes to one organism or to a small group; but as a rule there is a period when the plankton is reduced to a minimum in mid-summer and another in mid-winter.

Phyto-plankton.—If, as is customary, we group the Dinoflagellata (with, on the whole, a holophytic method of nutrition) along with the Diatoms, the phyto-plankton so constituted may be contrasted with the zoo-plankton in several respects. The Dinoflagellata have usually one well-marked peak or maximum in the year, and that lies somewhere between the extremes of April and August. Consequently the Dinoflagellates may be regarded as the characteristically summer phyto-plankton. The Diatoms, on the other hand, show two distinct maxima in the year —in spring and in late autumn, with usually a summer depression between. It thus seems that the conditions prevailing in summer (June, July and August) are unfavourable to a profuse development of Diatoms.

Winter is also unfavourable, and as a rule the period November to March shows the greatest reduction in phyto-plankton.

These results agree, on the whole, with those obtained by Lohmann in the Baltic, but his autumnal maximum of phyto-plankton seems to be greater than ours. The Dinoflagellate *Ceratium tripos*, according to Lohmann, begins in June, reaches its maximum in August and remains until October or November. With us this species is usually present all the year round, reaches a maximum in April to June and, with a few depressions, remains fairly high until August.

The spring Diatom rise began later and ended later this year than in the previous two years, and it is interesting to notice that our hydrographic observations in the Irish Sea show that both the temperatures and salinities were lower than usual this spring.

Zoo-plankton.—Changes in the volume of our zoo-plankton are almost entirely due to Copepoda, of which the most abundant forms in our district are *Oithona*,

Pseudocalanus and *Acartia*. The occurrence of these at Port Erin does not quite agree with that recorded by Lohmann for the Baltic. For example, *Oithona* is essentially an autumn form in the Baltic, and its maximum is in October and November. With us it is more constantly present, and may appear in quantity in various months; large numbers have been taken in January, July and August, as well as in October. *Acartia* also seems more widely spread with us, but our maximum in June to July probably corresponds to Lohmann's maximum in May. *Pseudocalanus* with us appears in quantity in October, and also in May-June, but is apparently not a conspicuous form in the Baltic.

On the whole, the Copepoda have their greatest abundance with us in early summer (May and June), and again in autumn (September). They were most depressed in '07 and '09 during February and March, and in '08 during January, February, July and August. There is usually a marked drop in the Copepoda about mid-summer, and this is sometimes followed (in July or early August) by a vast swarm of one species, such as *Calanus helgolandicus*.

As a rule the Dinoflagellate maximum in early summer is later than that of the Diatoms, but precedes that of the Copepoda. In the case of the less-marked autumnal maxima there is less constancy and less regularity in the order of succession.

Some organisms show a remarkable regularity in their time of appearance. For example, the nauplii of *Balanus* began to appear on February 22nd in '07, on February 13th in '08, and on February 6th in '09. This is one of the cases where it is clear that the normal sequence of events in the life-history of the organism is the dominant factor in determining the constitution of

the plankton at a definite time and place—the periodic reproduction of the *Balanus* causes the nauplii to appear in the plankton at a certain time.

Many other swarms of neritic, and especially mero-planktonic, forms (such as crab zoeas and fish eggs) are similarly due to the succession of stages in the life-history; but on the other hand, swarms of oceanic forms may be due to immigrations caused by unusual hydrographic or "weather" conditions. It does not seem possible, as yet, to determine the effect of the various factors—e.g., life-history and environmental conditions—in producing and terminating the great maxima, such as that of the Diatoms in spring. But we have given some evidence in favour of the view that increase in sunlight rather than any rise in sea-temperature precedes the vernal maximum of phyto-plankton.

The most populous zone in the sea is below the surface, but above 10 faths. The weighted net, ranging down to about 10 faths., usually gives larger hauls than the surface ones used at the same time. The organisms in this zone no doubt rise and fall to some extent as a result of weather conditions. Copepoda swarm on occasions at the surface, and on other occasions are more abundant a few fathoms below the surface. Diatoms, when present in abundance in spring, are sometimes found in increasing ratio from the surface down to 20 faths.

Certain organisms seem to be frequently distributed in shoals. This is, of course, normally the case with many larval forms, but is also common with, for example, *Calanus*, *Anomalocera*, *Temora*, and probably *Microcalanus*. We have referred above to certain large shoals of *Calanus*, and to an occasion when an unusual quantity of fish eggs was obtained from one spot.

In Port Erin Bay the organisms are on the whole chiefly neritic, the percentage of oceanic forms ranging, during the three years, from 30% to 60%. Mid-winter (December and January) and mid-summer (July) are markedly oceanic in character. The oceanic forms, although not always the most abundant, constitute the more permanent element of the plankton.

Fish eggs are commonest in the bay in March and April, the maximum occurring in April. They occur before that, rarely, in January and February, are present afterwards in fair numbers in May and June, decrease in July and August, and finally disappear in the beginning of September. The greatest haul was 258 in the coarse net on April 13th.

The catches inside Port Erin Bay give usually a very correct indication of the plankton in the open sea. Our numerous catches taken outside in spring and autumn do not differ much from those taken in the bay at the same time.

For conclusions as to the work of the different nets, and other details, reference must be made to the pages of the report above.

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